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PRELIMINARY INVESTIGATIONS INTO LEAD AND CADMIUM POLLUTION IN THE CITY OF EDMONTON

by

© JOHN WAYNE MAKSYLEWICH

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF CIVIL ENGINEERING

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled ..Preliminary..... Investigations into Lead and Cadmium Pollution in... The City of Edmonton..... submitted by ...John Wayne Maksylewich..... in partial fulfilment of the requirements for the degree of Master of Science.

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Abstract

Preliminary Investigations into Lead and Cadmium Pollution in the City of Edmonton

Preliminary investigations were made concerning the extent of automobile derived lead and cadmium pollution within the city of Edmonton.

The lead content of forty-four soil samples was found to vary from 25-720 mg/Kg of soil and the cadmium content of thirty-three samples varied from 0.5 - 1.2 mg/Kg of soil.

For forty-four water samples (drinking water and raw water) collected during the summers of 1973 and 1974 the lead values ranged from <0.001 - 0.014 mg/l and the cadmium values ranged from <0.001 - 0.005 mg/l.

Mean monthly atmospheric lead concentrations for air samples taken during January-December, 1973 and January-June, 1974 gave concentrations ranging from a low of 0.06 $\mu g/m^3$ for a residential area to a high of 0.7 $\mu g/m^3$ for a downtown location.

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CHAPTER I

INTRODUCTION

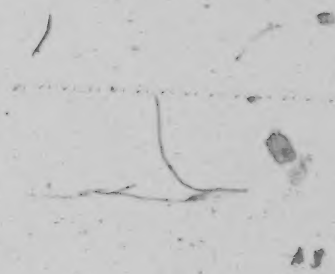
In recent years concern has been expressed regarding the production and distribution of lead and other metal aerosals. Numerous studies have shown that some of these are almost entirely derived from internal combustion engined vehicles. Lead aerosals have been shown to be mainly due to the combustion of gasolines containing lead alkyls, chiefly tetraethyl lead. The automobile has also been indicated as a source of cadmium compounds, specifically from the tires.

An examination of the number of automobiles in the city of Edmonton indicated that contamination by these two metals was likely. It was subsequently decided to do a preliminary investigation of lead and cadmium distributions and concentrations in air, water, plants and soils within the city of Edmonton.

Chapter II deals with the effects of lead and cadmium on the human organism; Chapter III with the distribution; Chapter IV with a description of the study area; Chapter V with the experimental methodology; Chapter VI with results and discussion and Chapter VII with summary and recommendations.

It is hoped that this work will serve as a

useful basis for further studies of this type within the Edmonton area.



CHAPTER II

Lead, Cadmium and the Human Organism

Effects of Lead

For over rwo thousand years it has been known that lead is toxic [3]. It has been proposed that the Roman civilization deteriorated largely as a result of lead poisoning among the ruling class, caused by extensive use of lead in cooking utensils, plumbing and in wine sweetening. High bone-lead concentrations in skeletal remains tend to support the theory [8].

The blood lead concentration of the average American exceeds one-fourth of that considered diagnostic for classical lead poisoning [3,7,22]. Numerous studies have shown that persons living in urban areas have higher body burdens of lead than those living in rural areas [16]. In Los Angeles the blood lead levels of persons living near freeways were higher than levels in persons living one mile away or in nearby coastal areas [5,22]. In Philadelphia the blood lead levels of persons who lived and worked within a twenty-five block radius of city hall were significantly higher than for persons who normally spent their entire time in the suburbs. The mean lead level of commuters was approximately midway between the two groups [23]. A study of Philadelphia males by Ludwig,

et al., (1965) showed that over 63% of downtown inhabitants had a blood lead concentration greater than 0.20 mg/l, while the 0.20 mg/l level was exceeded in only about 43% of the suburban males (Figure 1). Hernberg, et al., (1970) and Miller, et al., (1970) state that metabolic disturbance occurs above 0.20 mg/l.

Lead accumulates in many parts of the body, viz: bone, liver, kidneys, spleen, pancreas, lungs and blood [5,7]. The skeleton contains about 91% of the total body lead [20]. Most of the blood lead (ca. 95%) is found in the red blood cells [9].

Schroeder, et al., (1968) found that a balance between absorption and excretion seems to hold for some foreign subjects but not for Americans. Hardy (1969) states that the body lead content in old age is double what it is in adolescence and Goldsmith (1969) found increasing concentrations of lead with age in the liver, spleen, kidneys, pancreas and lungs of Americans with no such increases being found in the organs of foreign subjects from fairly primitive environments. Schroeder and Tipton (1968) found high lead concentrations in persons living in Hong Kong and other large far eastern cities.

Goldwater and Hoover (1967) stated that they found no variation in "normal" levels of lead in the blood and urine of subjects from various countries,

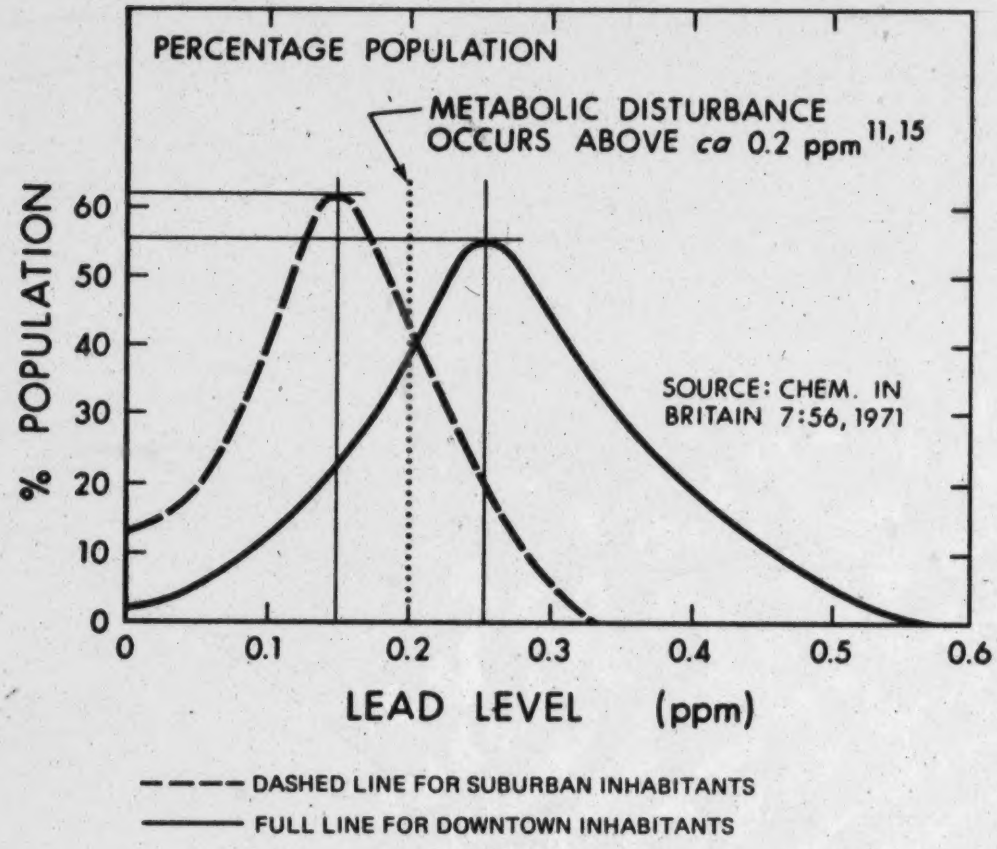


FIGURE I - Blood Lead Levels For Philadelphia Males, 1961-62

however, Goyer, et al., (1970) have shown that over a wide range of lead intake, the urinary lead concentration excreted is constant although renal lead concentration increases. In addition, about 95% of the blood lead is associated with the red blood cells and very little is found in the blood serum.

Acute lead poisoning causes extensive damage to the body: damage to the central nervous system, destruction of various brain tissues, degeneration of capillaries and blood vessels, blindness, paralysis, mental retardation, liver and kidney damage, reproduction failure and death [4,5,7,10,16,22]. Acute poisoning has easily recognized symptoms and usually if treatment is administered soon enough permanent damage is avoided. Chronic poisoning resulting from the slow buildup of lead concentrations is, however, more of a problem. Because early symptoms are vague and sometimes absent, diagnosis often occurs only after damage has been done.

Low-level exposure to lead (which is generally the case in most environmental situations) results in numerous biochemical changes, particularly in the hemoglobin synthesizing enzymes, resulting in inhibition of red blood cell production and subsequent development [2,4]. In addition, blood cell mobility, general enzyme activity, blood coagulation, resistance to disease and the lipid

metabolism are all affected detrimentally at blood lead levels of about 0.20 mg/l [2,4,5,11,15].

The major source of lead for most humans is the diet. Estimated oral ingestion of lead as the metal (from food and water) ranges from 300-400 micrograms per day [5,17,18]. Schroeder (1970) gives an absorption of about 10% for orally ingested lead which would result in a daily accretion of about thirty-five micrograms of the metal. The lungs retain about 30% of the lead inhaled from the atmosphere [13,14], and in regions of high atmospheric lead concentrations the inhaled lead can equal or exceed the oral contribution. Urban atmospheric lead concentrations have been found to range from 1 - 10 $\mu g/m^3$ (as the metal) and to exceed 40 $\mu g/m^3$ in traffic [3]. The average American adult inspires about 20 m^3 of air per day [17] which gives a conservative estimate of the daily contribution from the respiratory tract in the range of 7 - 70 µg of lead metal.

Animals exposed to high concentrations of atmospheric lead have been observed to exhibit symptoms of acute lead poisoning. Bozell (1971) reports that a large proportion of animals at the Staten Island and Bronx Zoos in New York City suffer from lead poisoning, apparently due to atmospheric sources.

Effects of Cadmium

While it is known that cadmium is several times more toxic than lead, comparatively little is known about the effects of cadmium on the human organism, particularly about the biological effects of small doses.

Cadmium is found mainly in the kidney, liver and pancreas where concentrations tend to increase with age [18, 19, 20], while other body tissues may or may not contain measurable quantities of the metal.

Cadmium induced changes in both animal and human physiology have been observed. Weber and Reid (1969) observed increased mortality among mice whose diets included cadmium and Morgan (1972) states that accelerated arteriosclerosis, hypertension and kidney disease have been induced in experimental animals by dietary cadmium. In humans, cadmium has been correlated with emphysema, bronchitis, hypertension and cardiovascular disease [12,16,18,19]. Available data indicate that in small doses cadmium inhibits organ functions and enzyme activity [20].

While the main source of cadmium for human beings is the diet, the fact that inhaled cadmium is almost entirely absorbed by the body indicates that airborne cadmium is a health hazard [18].

Chapter II

Footnotes

1. Bazell, R.J. Lead poisoning: Zoo animals may be first victims. Science 173:130, 1971.
2. Chisalm Jr., J.J. Lead Poisoning. Scientific American 224 : 15, 1971
3. Craig, P.P., Berlin, E. The air of poverty. Environment 13 : 2, 1971.
4. de Bruin, A. Certain biological effects of lead upon the animal organism. Arch. of Env. Health 23 : 249, 1971.
5. Goldsmith, J.R. Epidemiological bases for possible air quality criteria for lead. JAPCA 19 : 714, 1969.
6. Goldwater, L.J., Hoover, A.W. An international study of normal levels of lead in blood and urine. Arch. Env. Health 15 : 60, 1967.
7. Goyer, R.A., Leonard, D.L., Moore, J.F., Rhyne, B., Kregman, M.R. Lead dosage and the role of the intranuclear inclusion body. Arch. Env. Health 20 : 705, 1970.
8. Hall, S.K. Pollution and Poisoning. EST 6 : 31, 1972
9. Hardy, H.H. Discussion of article by Kehoe. JAPCA 19 : 701, 1969.
10. Hardy, H.L. Lead and health. Environment 10 : 80, 1968.

11. Hernberg, S., Nikkanen, J. Enzyme inhibition by lead under normal urban conditions. Lancet 1 : 63, 1970.

12. Hickey, R.J., Schoff, E.P., Clelland, R.C. Relationship between air pollution and certain chronic disease death rates. Arch. Env. Health 15 : 278, 1967.

13. Kehoe, R.A. Toxicological appraisal of lead in relation to the tolerable concentration in the ambient air. JAPCA 19 : 690, 1969.

14. Ludwig, J.H., Diggs, D.R., Hesseburg, H.E., Maga, J.A. J. Amer. Ind. Hyg. Ass. 26 : 270, 1965.

15. Miller, J.A., Battistini, V., Cumming, R.L.C., Carswell, F., Goldberg, A. Lead and δ-aminolevulinic acid dehydratase levels in metally retarded children and in lead-poisoned suckling rats. Lancet 1 : 695, 1970.

16. Morgan, M.J. Normal lead and cadmium content of the human heart. Arch. Env. Health 24 : 364, 1972.

17. Patterson, C.C. Contaminated and natural lead environments of man. Arch. Env. Health 11 : 344, 1965.

18. Schroeder, H.A. Cadmium as a factor in hypertension. J. Chron. Dis. 18 : 647, 1965.

19. Schroeder, H.A. A sensible look at air pollution by metals. Arch. Env. Health 21 : 798, 1970.

20. Schroeder, H.A., Balassa, J.J. Abnormal trace metals in man: Cadmium. J. Chron. Dis. 14 : 236, 1961.

21. Schroeder, H.A., Tipton, I.H. The human body burden of lead. Arch. Env. Health 17 : 965, 1968.

22. Stankovic, M.K. Biochemical tests for the appraisal of exposure to lead. Arch. Env. Health 23 : 265, 1971.

23. Thomas, H.V., Milmore, B.K., Heidbreder, G.A., Kogan, B.A. Blood lead levels in persons living near freeways. Arch. Env. Health 15 : 695, 1967.

24. Weber, C.W., Reid, B.L. Effect of dietary cadmium on mice. Tox. Appl. Pharm. 14 : 420, 1967.

CHAPTER III

Lead and Cadmium in the Environment

Sources of Lead

Available data indicate that the combustion of gasolines containing antiknock lead compounds is the major source of the present world wide lead pollution [5,8,9,11] (Figure 2). Since the introduction of lead alkyls in 1923 more than 5.5×10^{14} gm (1.2×10^{12} lb) of lead metal have been consumed for this purpose in the United States alone [9]. At present the lead in lead alkyls accounts for some 20% of the lead consumed annually in the United States [27]. In Los Angeles over 1.36×10^{7} gm (3.0×10^{4} lb) of lead metal is exhausted into the atmosphere every twenty-four hours [19].

U.S. Gasoline has been reported to contain from 2.5 - 5 gm/Imp.gal. of lead alkyls [18]. In October, 1973 gasoline produced in Canada by Gulf contained 1.5 gm/Imp. gal. of lead metal in regular gasoline and 2.0 gm/Imp. gal. in premium [40].

In low speed driving situations some 20 - 40% of the available lead is exhausted into the atmosphere [1]. The remainder, which is retained by the engine and exhaust system, is exhausted at higher freeway speeds along with almost all gasoline lead [1,11]. Particulate matter emitted by car exhausts is largely composed of lead compounds

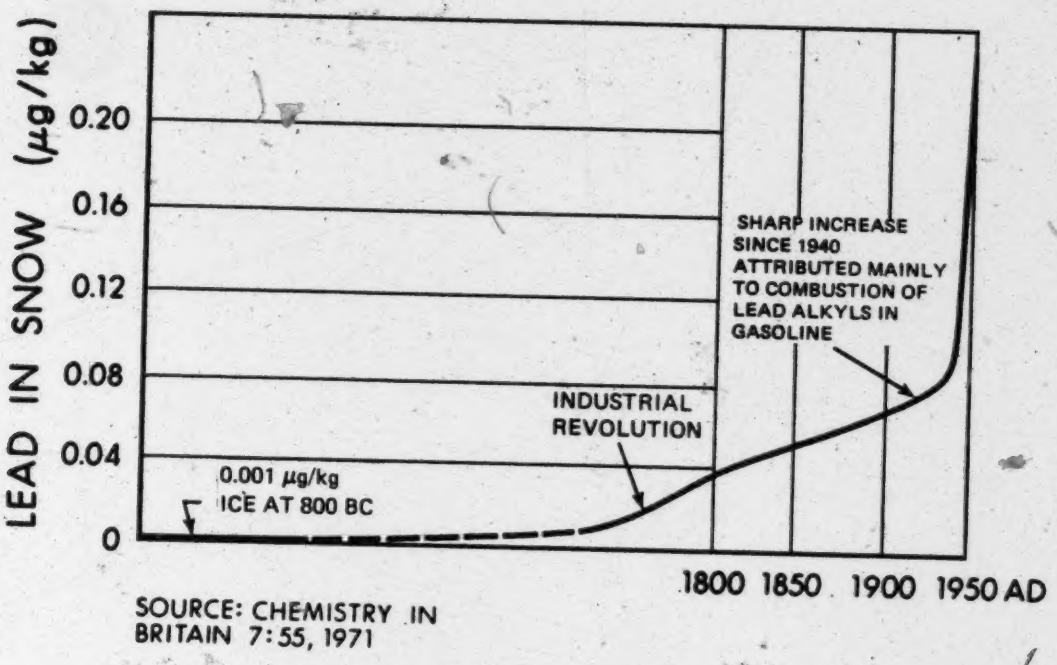


FIGURE 2 - LEAD CONTENT OF GREENLAND SNOW LAYERS

(30 - 60% by weight as the metal) [8].

The results of the combustion of leaded gasolines is that the highest lead levels are found in and around automobiles in high-speed, high-density freeway traffic [1,12,27].

Lead Distribution

Over 90% of lead in automobile exhausts is inorganic [27,30], much of it lead halides [27,28]. Particle sizes range from about 0.01 μ to larger than 1.0 μ. About 75% have a mean diameter less than 1.0 μ and about 25% have a mean diameter larger than 1.0 μ. Results from Lee, et al., (1968) showed a distribution as follows: about 65% < 1.0 μ mean diameter and about 73% < 2.0 μ mean diameter for Fairfax, a Cincinnati suburb, and for downtown Cincinnati about 75% < 1.0 μ and about 83% < 2.0 μ. Junge (1963) showed that particles < 1.0 μ mean diameter compose about 35% of the total particle mass and particles of mean diameter < 2.0 μ compose about 50% of the total mass.

Gillette (1972) and Gillette and Winchester (1972) give evidence that particle size distribution of lead aerosols do not vary greatly from one source area to another; furthermore, the size distribution does not respond noticiably to change of weather within the source area for twenty-four hour sampling periods. Small particles

tended to coagulate and add to the $0.05\mu \leq r \leq 0.5\mu$ range. Removal from this range by coagulation was very slow. Gravimetric sedimentation was an important removal mechanism only for large particles ($r > 1\mu$) and inertial impact was the prime removal mechanism for smaller particles ($r < 1\mu$). They estimate that about 17-50% of the total mass of exhausted lead is deposited on soils, roadways and waters near the emission site. The rest (50-83%) remains in the air for varying lengths of time, depending upon turbulence, impact site availability and precipitation.

Atmospheric Lead Concentrations

No part of the world is free from atmospheric lead. Patterson (1965) gives a mean concentration of lead in soils and rocks of about 15 mg/Kg. On this basis, Chow et al., (1969) estimate that the natural lead concentration in north and central Pacific marine air should be $1 - 30 \times 10^{-6}$ $\mu g/m^3$. They found a mean of 1×10^{-3} $\mu g/m^3$ indicating airborne pollution. Chow and Earl (1970) have shown conclusively via isotope ratio measurements, that gasoline combustion is the main source of atmospheric lead pollution, and an essentially linear correlation has been shown to exist between lead concentrations in air and traffic density [6].

Levels of lead in urban air range from about 1 - 10 $\mu g/m^3$ (Table I) but near heavy traffic they often exceed 40 $\mu g/m^3$ [13,14,30,33], and a level of 71.3 $\mu g/m^3$ has been recorded [13]. A peak concentration of 107 g/m^3 has been recorded at the driver's seat of a stationary automobile [5]. These figures contrast with the 1.5 $\mu g/m^3$ limit adopted by the California Air Resources Board and the legal limit of 0.7 $\mu g/m^3$ set by the Soviet Union [13].

Lead in Soils

The mean background soil lead concentration is usually accepted as about 15 mg/Kg [33]. In dusts from city streets concentrations of lead metal up to 1% (10,000 mg/Kg) have been reported [13]. Acid extractions of soil samples taken adjacent to highly travelled roadways typically give values of several hundred milligrams of lead metal per kilogram of dry soil (Table 2).

It has been shown that for a given distance from the source, soil lead increases with increasing traffic density [31]. The lead localizes in the top few centimeters of soil [17,21,31]. The lead concentration decreases rapidly with increasing distance from the source [31].

Colucci et al., (1969) found that for all cities studied the lowest soil lead concentrations were in suburban residential sites.

Table 1. Air Lead Concentrations for Foreign Cities

City	Conditions	Concentration ($\mu g/m^3$)
Frankfurt, Ger. (1971)[14]	temperature inversion	38
Berlin (1971) [14]	mean in heavy traffic	3.8
	maximum in heavy traffic	7.4
Thule, Greenland (1969)[18]	mean	0.01
Los Angeles (1972) [19]	mean	5.0
Other communities [19]	$<2 \times 10^6$ population	2.5
	$<1 \times 10^6$ population	2.0
	$<1 \times 10^5$ population	1.7
Cincinnati (1966) [29]	mean	2.78
Philadelphia (1965) [29]	mean	0.69
Los Angeles (1961) [30]	mean	2.5
	heavy traffic (mean)	25
Philadelphia (1965) [30]	mean	1.6
	heavy traffic (mean)	14

(Table continued)

Table 1 continued

City	Conditions	Concentration ($\mu g/m^3$)
Cincinnati (1965) [30]	mean	1.4
San Diego [13]	maximum weekly mean (1957)	1.1
	maximum weekly mean (1966)	1.8
	maximum weekly mean (1970)	8.0
Fairbanks, Alaska (1967) [39]	city center	6.0
	outside city	0.19

Table 2. Lead in Surface Dirt from Foreign Cities [12]

City	Site and Specific Area	Lead (mg/Kg)	
Detroit	Lodge-Ford Freeway interchange		
	Street near interchange	Through 40 mesh screen	1500
		On 40 mesh screen	100
	Shoulder of road	Through 40 mesh screen	1300
	Shoulder of road	Through 40 mesh screen	1300
		On 40 mesh screen	600
	Grand Circus Park		
	Parking lot	Pulverized	2100
	Between curb and sidewalk	Pulverized	600
New York	10th Ave. and 40th St. at curb (not on air sampling site)	Pulverized	1800
Los Angeles	Pico Boulevard		
	Grassy area between curb and sidewalk	Pulverized	8600
	Street at curb	Pulverized	5800

(Table continued)

Table 2 continued

City	Site and Specific Area		Lead (mg/Kg)
	Harbor-Santa Monica Free. Int.		
	Street at curb near interchange	Pulverized	3000
	Paved area under interchange	Pulverized	6800
	Unpaved area under interchange	Pulverized	100
	Santa Monica		
	Grassy area between curb and sidewalk	Pulverized	1400
	Street at curb	Pulverized	5400
	Monrovia		
	Street at curb	Pulverized	2900
	Flower bed between curb and sidewalk	Pulverized	2600
New York	Street dirt		2600
Cincinnati	Top soil (six samples)		16-360

(Table continued)

Table 2 continued

City	Site and Specific Area	Lead (mg/Kg)
Zurich, Switzerland	Streets with motor traffic (171 samples)	100-3200
	Streets with no motor traffic (7 samples)	0-18
Mexico	Dust in rural, non-industrial areas	0.6-6

Lead in Water

Although water is recognized as a source of dietary lead and standards have been established for lead in drinking waters there is little information regarding natural and contaminated lead levels. Lazarus, et al., (1970) have shown there are significant amounts of lead in precipitation, and other researchers [9,33,34] have found automobile derived lead in snow and glacial ice.

Pitt and Field (1974) give data to show that urban storm water is a large source of lead contamination for receiving bodies of water and Oliver (1973) showed that river sediments where snow dumps have existed have high concentrations of lead compared to background sediments.

Sources and Distribution of Cadmium

Comparatively few studies have been performed on the sources and distribution of cadmium in the environment. Cadmium is found as a trace contaminant associated with zinc in galvanized coatings, oils, tires, superphosphate fertilizers, fungicides and tobaccos [22,23,35,36]. The main source of the metal in urban areas seems to be tires and oils [22]. Grains and grain products contain appreciable amounts of cadmium due to the use of phosphate fertilizers.

There is little data available on background cadmium concentrations, but Klein (1972) gives mean values of 0.41 mg/Kg for residential areas, 0.57 mg/Kg for agricultural areas, 0.66 mg/Kg for industrial areas and 0.77 mg/Kg for an airport. John (1972, 1973) found that the amount of nitric acid soluble cadmium present in some agricultural soils ranged from undetectable to 4.67 mg/Kg.

Lagerwerff and Specht (1970) found that cadmium concentrations varied with traffic density, distance from roadway and soil depth. Their analysis of lubricating oils and automobile tires gave 0.20 - 0.26 mg/Kg and 20 - 90 mg/Kg cadmium respectively. No cadmium was detectable in gasolines analyzed.

Lead and Cadmium in Plants and Animals

Evidence conclusively shows that plants growing along roadways take up lead and cadmium and have it deposited on their surfaces. Vegetables grown within twenty-five feet of a street averaged 80 - 115 mg/Kg of lead woody plants in an urban area were shown to have high lead concentrations [37], and various food crops hve been shown to take up cadmium [23].

Animals living near roadways and/or eating vegetation from this area displayed high lead concentrations. Invertebrates and small mammals found near a heavily

travelled roadway had high lead concentrations with animals found closest to the road having the highest concentrations [20]. Bovay et al. (1970) and Blanc et al. (1971) have shown that cows fed on grass harvested along a busy highway accumulated lead, notably in stomach, intestines, blood and milk. Goodman and Roberts (1972) observe that a horse fed on contaminated grass died from acute lead poisoning.

Chapter III

Footnotes

1. Atkins, P.R. Lead in a suburban environment. JAPCA 19 : 591, 1969

2. Blanc, B., Hofmann W., Basset, J., Graber, H., Liechti, D., Bovay, E. Schweizeriche Landwirt Schaftleiche Forchung 9 : 159, 1970

3. Bovay, E. Schweizerische Gesellschaft fuer Analytiche und Angewandte Chemie 61 : 303, 1970

4. Bovay, E., Hofmann, W., Zuber, R., Kuepfer, U., Gisiger, L., Blanc, B. Schweizerische Landwirt Schaftliche Forchung 9 : 159, 1970

5. Brief, R.S. Air lead concentrations from automobile engines. Arch. Env. Health 5 : 527, 1962

6. Brief, R.S., Jones, A.R., Yoder, J.D. Lead, carbon monoxide and traffic: A correlation study. JAPCA 10 : 384, 1960

7. Cannon, H.L., Bowles, J.M. Contamination of vegetation by tetraethyl lead. Science 137 : 765, 1962

8. Charlson, R.J., Pierrard, J.M. Visibility and lead. Atm. Env. 3 : 479, 1969

9. Chow, T.J., Earl, J.L. Lead aerosols in the atmosphere: Increasing concentrations. Science 167 : 577, 1970

10. Chow, T.J., Earl, J.L., Bennett, C.F. Lead Aerosols in Marine Atmospheres. Env. Sci. Tech. 3 : 737, 1969

11. Chow, T.J., Johnstone, M.S. Lead aerosols in gasoline and aerosols in Los Angeles basin, California. Science 147 : 502, 1965

12. Colucci, J.M., Begeman, C.R., Kumler, K. Lead concentrations in Detroit, New York and Los Angeles air. JAPCA 19 : 255, 1979

13. Craig, P.P., Berlin, E. The air of poverty. Environment 13 : 2, 1971

14. Georgii, H.W., Jost, D. Short communication: On the lead concentration in an urban aerosol. Atm. Env. 5 : 725, 1971

15. Gillette, D.A. A study of aging of lead aerosols - II. Atm. Env. 6 : 451, 1972

16. Gillette, D.A., Winchester, J.W. A study of aging of lead aerosols - I. Atm. Env. 6 : 433, 1972

17. Goodman, G.T., Roberts, T.M. Plants and soils as indicators of metals in the air. Nature 231 : 287, 1972

18. Grundy, R.D. Summary: Toxicological and epidemiological bases for air quality criteria. JAPCA 19 : 730, 1969

19. Hall, S.K. Pollution and poisoning. Env. Sci. Tech. 6 : 31, 1972

20. Jeffries, D.J., French, M.C. Lead concentrations in small mammals trapped on roadside verges and field sites. Env. Poll. 3 : 147, 1972

21. John, M.K. Lead contamination of some agricultural soils in Western Canada. Env. Sci. Tech. 5 : 1199, 1972

22. John, M.K. Cadmium contamination of soils and its uptake by oats. Env. Sci. Tech. 6 : 555, 1972

23. John M.K. Cadmium uptake by eight different food crops as influenced by various soil levels of cadmium. Env. Soil. 4 : 7, 1973

24. Junge. C.E. Air Chemistry and Radioactivity, Academic Press, New York, 1963

25. Klein, D.H. Mercury and other metals in urban soils. Env. Sci. Tech. 6 : 560, 1972

26. Lagerwerff, J.V., Specht, A.W. Contamination of roadside soil and vegetation with Cd, Ni, Zn, Pb. Env. Sci. Tech. 4 : 583, 1970

27. Landau, E., Smith, R., Lynn, D.A. Carbon monoxide and lead: An environmental appraisal. JAPCA 19 : 684, 1969

28. Lazarus, A.L., Lorange, E., Lodge, Jr., J.P. Lead and other metal ions in U.S. precipitation. Env. Sci. Tech. 4 : 55, 1970

29. Lee, Jr., R.E., Patterson, R.K., Wageman, J. Particle-size distribution of metal components in urban air. Env. Sci. Tech. 2 : 289, 1968

30. Ludwig, J.H., Diggs, D.R., Hesselburg, H.E., Maya, J.A. Survey of lead in the atmosphere of three urban communities: A summary. J. Amer. Ind. Hyg. Ass. 26 : 270, 1965

31. Motto, H.L., Daines, R.H., Chilko, D.M., Motto, C.K. Lead in soils and plants: Its relationship to traffic volume and proximity to highways. Env. Sci. Tech. 4 : 231, 1970

32. Oliver, B.C. Heavy metal levels of Ottawa and Rideau River sediments. Env. Sci. Tech. 7 : 135, 1973

33. Patterson, C.C. Contaminated and natural lead environments of man. Arch. Env. Health 11 : 344, 1965

34. Pitt, R.E., Field, R. Water quality effects from urban runoff. AWWA Conference, Boston, U.S.A., 1974

35. Schroeder, H.A. A sensible look at air pollution by metals. Arch. Env. Health 21 : 798, 1970

36. Schroeder, H.A., Babassa, J.J. Abnormal trace metals in man: Cadmium. J. Chron. Dis. 14 : 236, 1961

37. Smith, W.H. Lead and mercury burden of urban woody plants. Science 176 : 1237, 1972

38. Tatsimoto, M., Patterson, C.C. Concentrations of common lead in some Atlantic and Mediterranean waters and in snow. Nature 199 : 350, 1963

39. Winchester, J.W., Zoller, W.H., Duce, R.A., Benson, C.S. Lead and halogens in pollution aerosols and snow from Fairbanks, Alaska. Atm. Env. 1 : 105, 1967

40. Private communication. Environment Canada, August, 1974

CHAPTER IV

Description of Study Area

Soil Sampling Locations

In Edmonton, a city of about 500,000 population, there were about 170,000 passenger automobiles in 1973. At present, there is extensive commuting and high traffic densities existing. (Table 3, Figures 3,4)

The city is divided roughly in half by the North Saskatchewan River and a large percentage of the total traffic flow utilizes the various bridges spanning the river. As a result of this high density traffic it can be expected that areas close to the bridges would be among those most heavily contaminated with automobile derived pollutants, specifically lead and cadmium. On this basis, areas immediately adjacent to the exits and entrances of four bridges were chosen as sampling points for a determination of lead levels: Low Level Bridge, High Level Bridge, 105th Street Bridge and James MacDonald Bridge. Subsequent experimental results showed that cadmium levels were low and consequently only the latter two bridges were used for cadmium determinations. The first of these is a new bridge with about three years use and it was expected that it would be the least contaminated. The other three bridges have seen extensive use for ten or more years (Figure 6).

Table 3. Cross River Automobile Traffic for the City of Edmonton

Source - City of Edmonton, 1974

Bridge	1968		1969		1970		May, 1973		Oct., 1973	
	ADT*	%**	ADT	%	ADT	%	ADT	%	ADT	%
Low Level	42,500	25	43,000	25	41,700	23	30,600	14	30,500	13
105 Street	27,600	18	28,200	16	27,400	16	30,000	13	32,800	14
High Level	23,800	14	23,200	13	22,900	13	23,370	10	23,800	10
James MacDonald							25,803	11	26,700	12

*ADT - average daily traffic (24 hour volumes)

**% - % of total average daily traffic across river

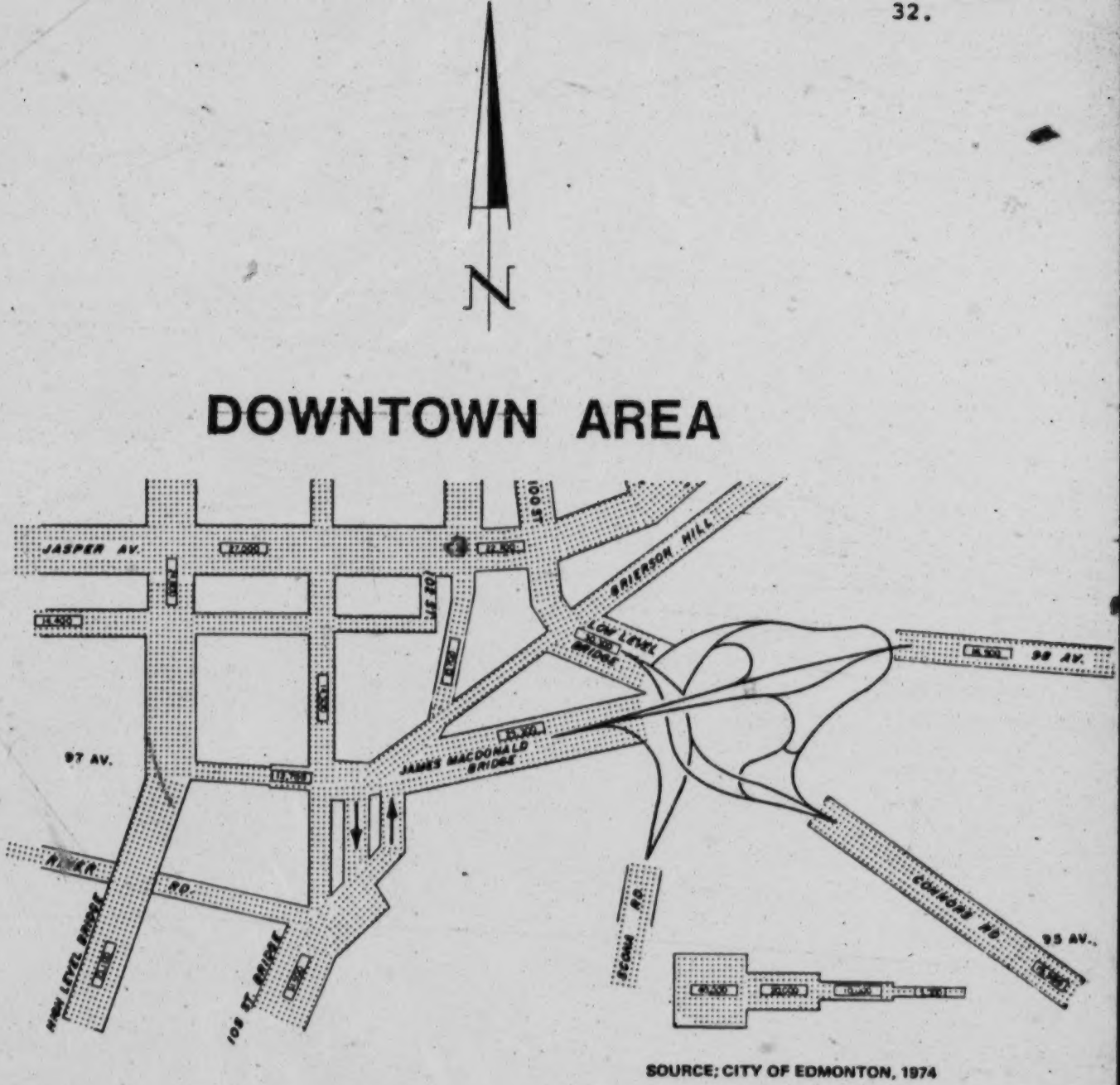


FIGURE 3 - Average Annual Weekday Traffic - 1973

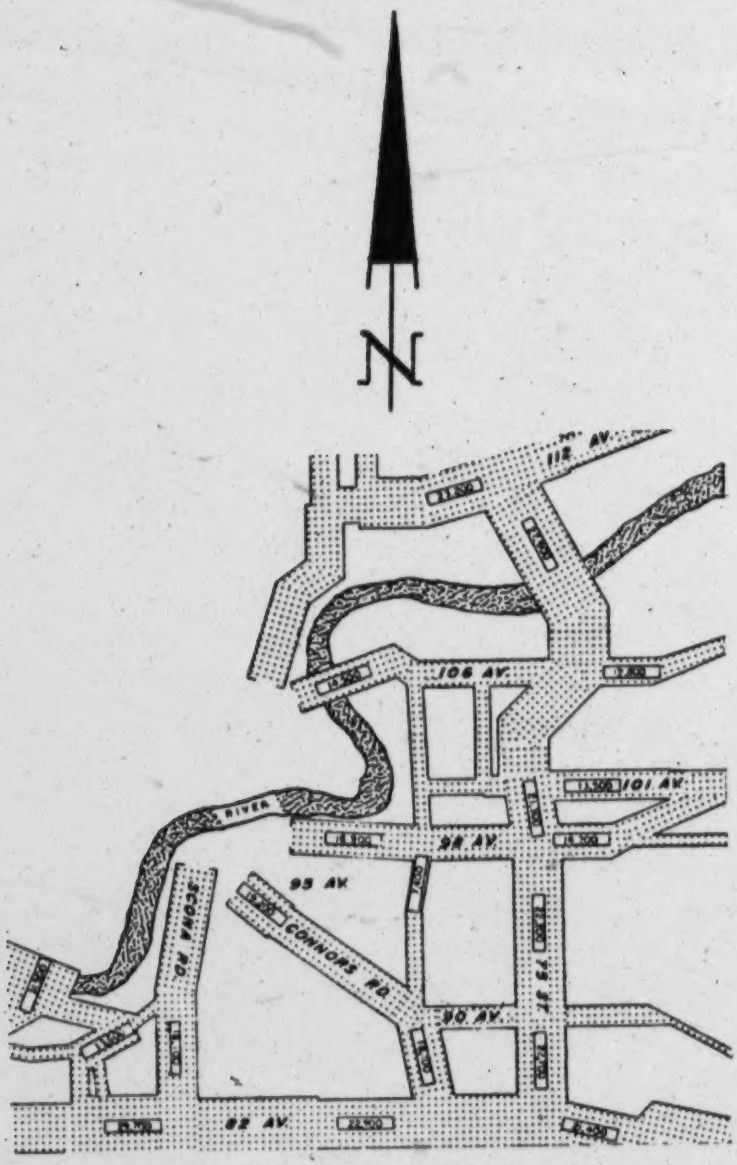


FIGURE 4 - Average Annual Weekday Traffic For The Vicinity Of The 98 Avenue 85 Street Traffic Circle - 1973

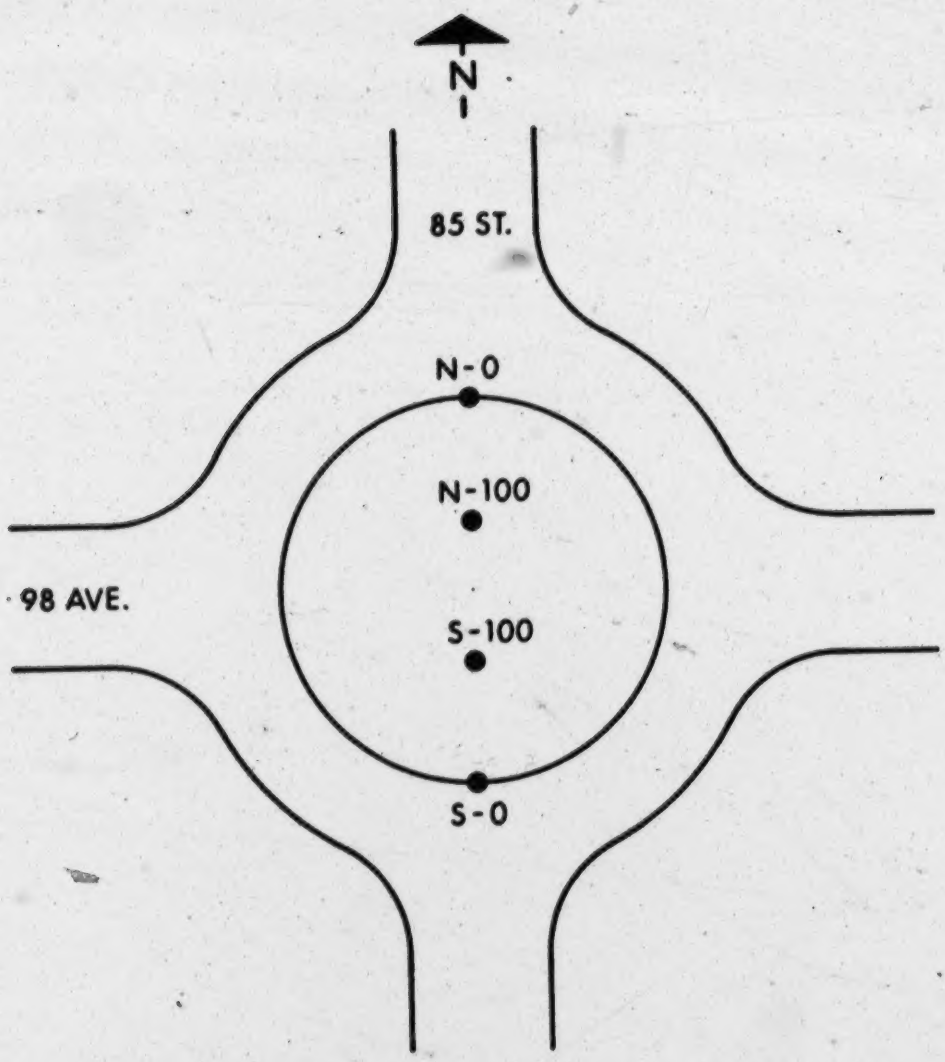


FIGURE 5 - SCHEMATIC OF 98 AVENUE 85 STREET TRAFFIC CIRCLE SHOWING TRANSECTS

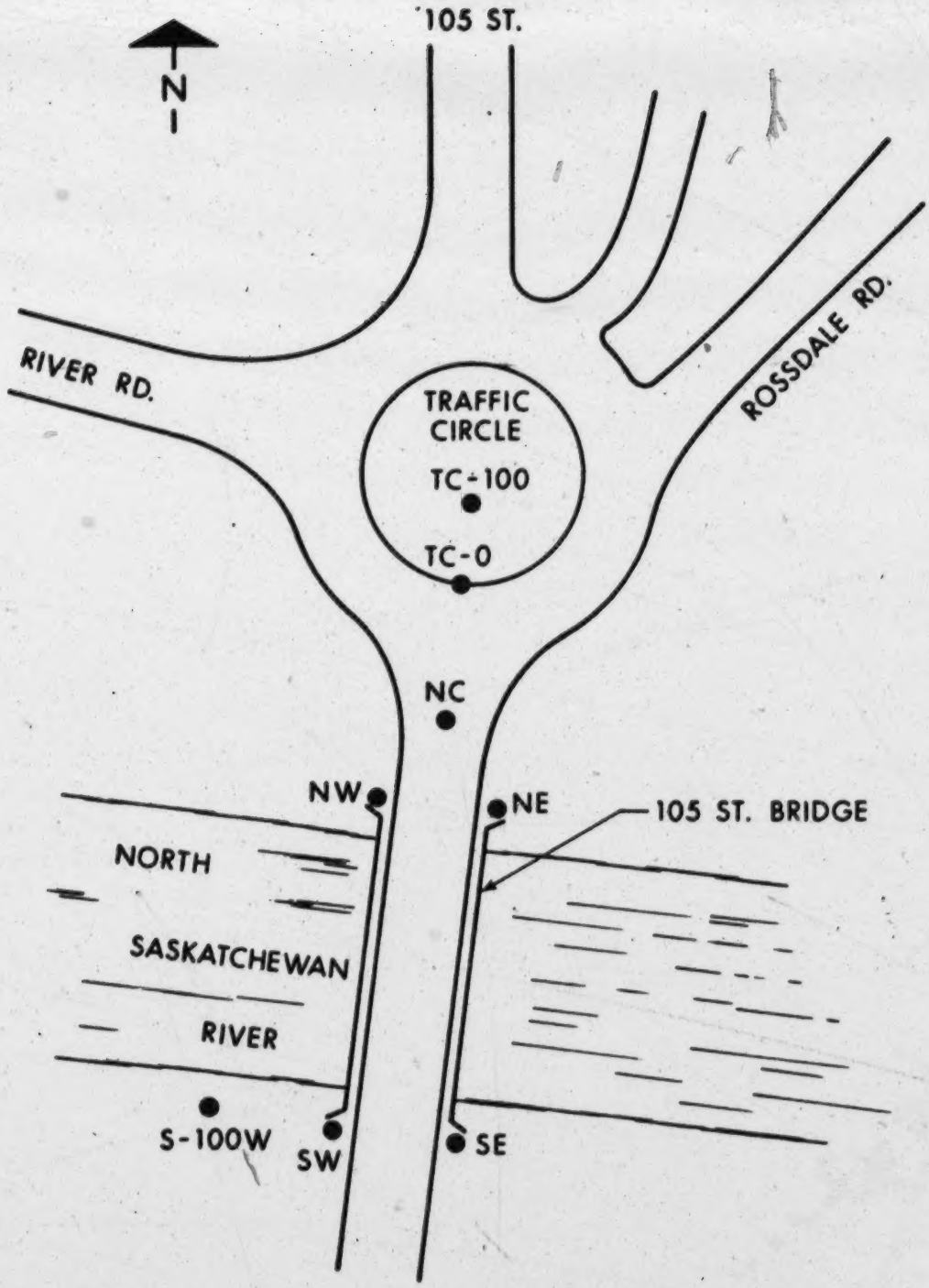


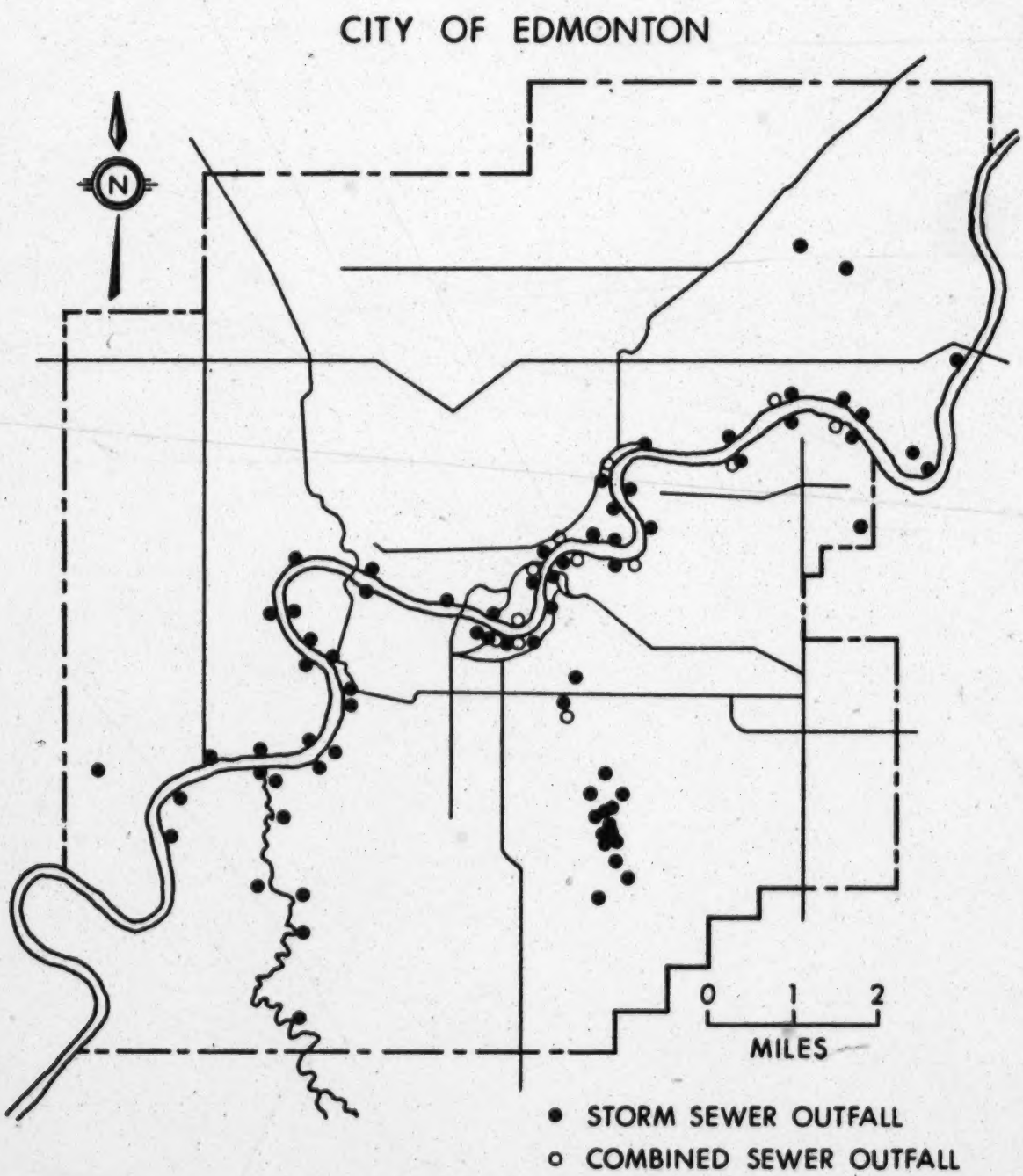
FIGURE 6 - REPRESENTATIVE SCHEMATIC FOR BRIDGES SHOWING SAMPLE SITES - 105 STREET BRIDGE

One of Edmonton's traffic circles was chosen for an evaluation of the lateral distribution of lead and cadmium. The traffic circle chosen is located at 98 Avenue and 85 Street, and until the construction of the James MacDonald Bridge in 1972 experienced comparatively low traffic flows (Figure 5).

Water Sampling Locations

The North Saskatchewan River performs a number of functions for the City of Edmonton. It is utilized for recreation, a source of municipal and industrial process water, the municipal drinking water source and as a receptor for various wastes. With two exceptions, all wastes enter the river downstream from the Edmonton Water Treatment Plant raw water intake (located on the north side of the river just below the 105 Street Bridge) and therefore have no effect upon City of Edmonton drinking water quality. The two exceptions are a number of storm sewer outfalls and some snow dumps (Table 4, Figure 7).

Snow dumps are created during the winter when snow from street cleaning operations is piled on the river ice and adjacent shore. When the ice breaks up in spring, with about 3 - 4 days the snow in the river is washed down. At approximately this same time (depending upon weather conditions), melting snow also flushes the streets, the effluent passing through the storm sewer system into



SOURCE: CITY OF EDMONTON, 1974

FIGURE 7 - Storm Sewer Outfall Locations - 1973

Table 4. Storm Sewer Outfalls into the North Saskatchewan River Above the Municipal Drinking Water Intake 1973.

Source - City of Edmonton, 1974

	Number/ Diameter	Location
1.	24"	Approximately 105 Street - north side of river - south of traffic circle.
2.	2x8" 2x10"	Along River Road - north side of river - between High Level Bridge and 105 Street Circle.
3.	8"	Below High Level Bridge - north side of river.
4.	27"	Below Royal Glenora Club - north side of river.
5.	7x(10" or 12")	On River Road Between Royal Glenora Club and Groat Bridge.
6.	48"	East of Groat Bridge - south side of river - Emily Murphy Park.
7.	15"	Below Groat Bridge - south side of river.
8.	66"	Ravine below Riverside Drive - north of Valleyview Drive - north side of river.
9.	24"	Below Mayfair Park - south side of river.
10.	Several	24" and 27" Mayfair Park Road
11.	60"	Approximately 89A Avenue - north side of river.
12.	54"	On Buena Vista Road - north side of river - east of Zoo

(Table continued)

Table 4 continued

13.	15"	Below Sask. Drive - on south side of river - north of University Avenue.
14.	30"	Below Sask. Drive - on south side of river - south of University Avenue.
15.	15"	Below Sask. Drive - on south side of river - north of 78 Avenue.
16.	15"	Below Sask. Drive - on south side of river - on 74 Avenue.
17.	60"	N. of Whitemud Road - on south side of river - W. of Sask. Drive.
18.	96"	Below Quesnell Bridge on north side of river.
19.	72"	Below Quesnell Bridge on south side of river.
20.	36"	Rio Terrace Road - north side of River west of 149 Street.
21.	30"	Approximately 56 Avenue, south side of river - west of Riverbend. In addition there are 7 outfalls into Whitemud Creek, between 30th Avenue and the river, of sizes (from south to north) : 72", 36", 72", 48", 42", 48" and 24", and 120" storm sewer draining into Kennedale Ravine.

the river. As there is approximately a six month accumulation of automobile emissions in and on the snow it can be expected that significant amounts of lead and cadmium would be carried into the river, primarily from storm sewer runoff and, to a lesser extent, from the snowdumps.

During rainfall in the summer and fall, street contaminants are also washed into the sewer. The accumulation period here is much shorter, and the net lead and cadmium concentration should be significantly lower.

Rather than sample the numerous storm sewers, it was decided to determine the lead and cadmium concentrations in raw water entering and treated water leaving the Edmonton Water Treatment Plant. From this it was expected that an estimate of the contribution of lead and cadmium by drinking water could be made. Since there are only two snowdumps located upstream (Groat Road, Whitemud Creek) it was decided to sample both of these to determine their effect upon the river quality.

Air Sampling Locations

A portable high volume air sampler was not available and consequently it was arranged to use data compiled from the three fixed samplers utilized by the Provincial Department of the Environment. The Department air samples three representative areas of the city:

downtown at 102 Avenue and 100 Street, a residential site at 92 Avenue and 146 Street and an industrial site at 17 Street and 100 Avenue.

Vegetation Sampling Locations

Numerous investigators have shown that plants growing in soils containing lead and cadmium can contain increased concentrations of metals. Leaf samples from about the four foot level were taken for lead and cadmium analysis from trees growing near the soil sample sites.

CHAPTER V

Experimental Procedures

Lead and Cadmium Standard Curves

Separate stock 1000 mg/l lead and cadmium solutions were prepared by dissolving appropriate amounts of lead nitrate (J.T. Baker Co.) and cadmium oxide (J.T. Baker Co.) in a minimum volume of concentrated nitric acid (C.I.L.) and diluting to volume with standard one molar nitric acid. Working solutions were prepared daily be successive dilutions of the stock solutions.

Samples containing 0, 5, 10, 25, 40, 50 mg/l of lead were prepared for the standard curve (Figure 9). The calibration curve for cadmium was obtained from samples containing 0, 0.1, 0.25, 0.5 and 1.0 mg/l cadmium (Figure 8).

Analysis of samples and standards for lead was performed on a Perkin Elmer 290-B atomic absorption instrument using the 2833 Å lead absorption line. A second instrument was utilized for cadmium using the 2288 Å cadmium line. An air/acetylene flame was used with fuel/oxidant ratios adjusted for maximum sensitivity. A 7 Å slit width was used for both elements.

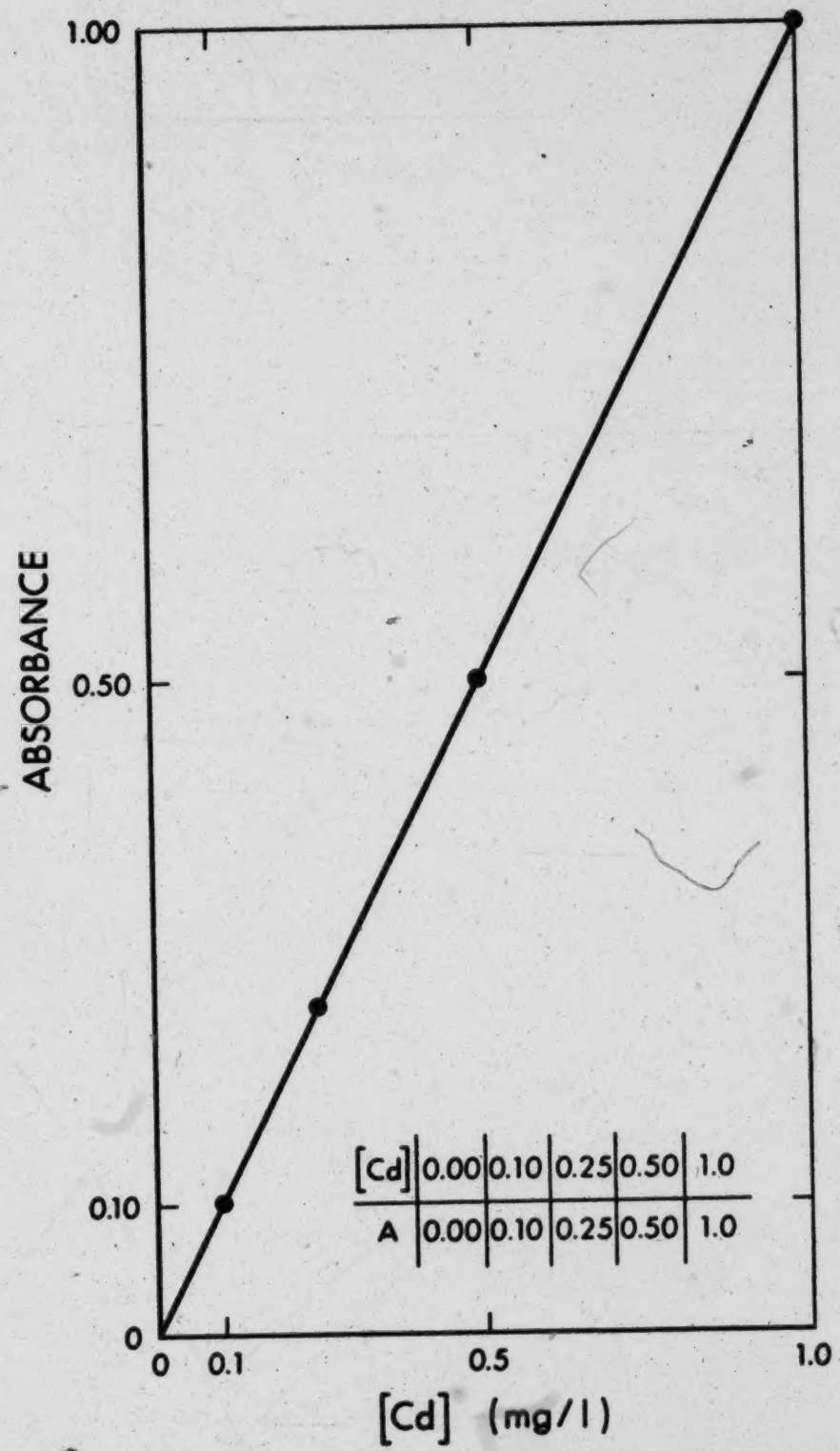


FIGURE 8 - Calibration Curve For Cadmium [0 - 1.0 ppm]

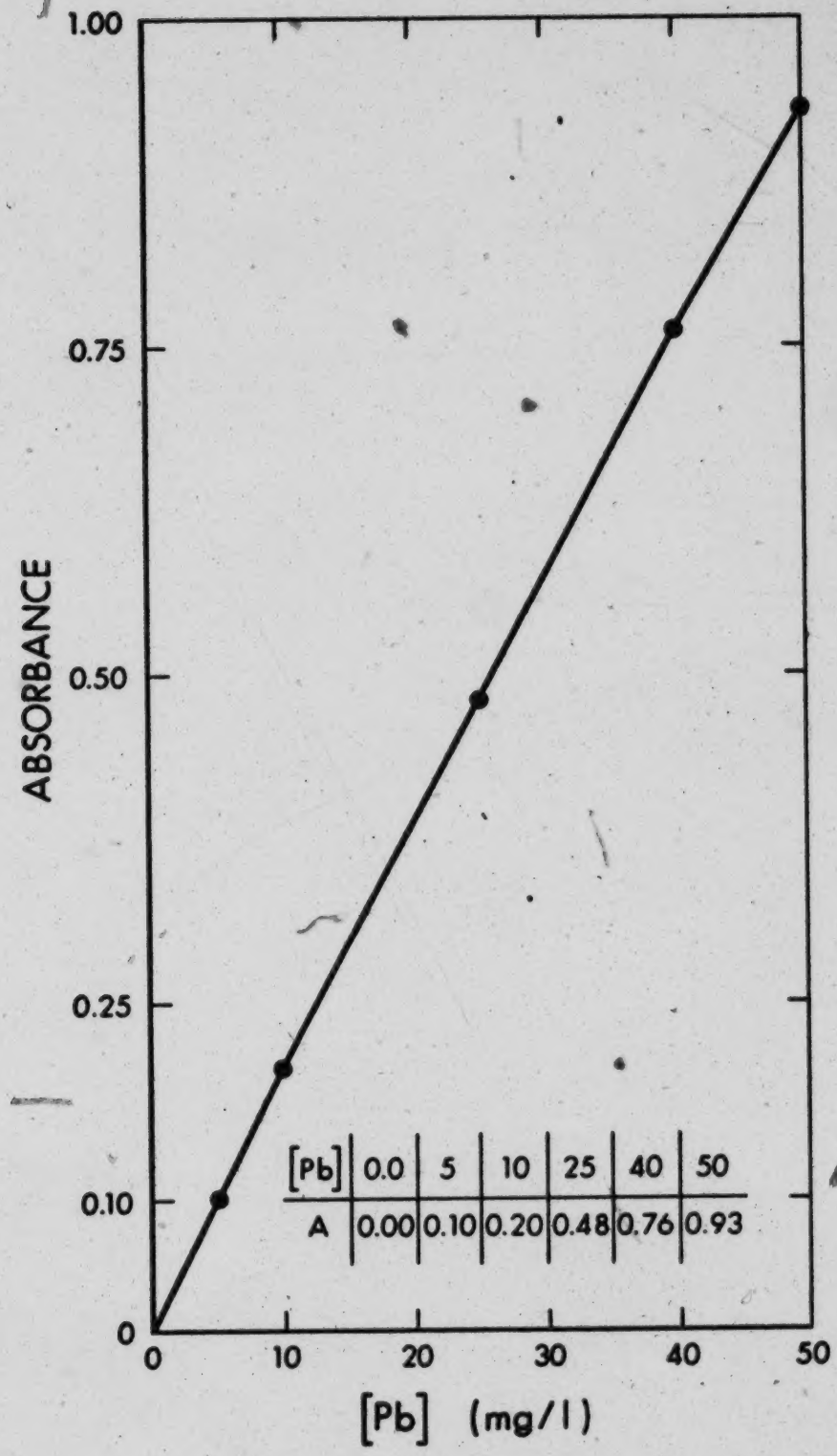


FIGURE 9 - CALIBRATION CURVE FOR LEAD [0 - 50 PPM]

Soil Analysis Procedure

A method of extraction which will provide an accurate measure of non-native lead and cadmium in soil is necessary. A procedure as utilized by John (1971) and Klein (1972) was selected for this purpose.

Small areas (about 10 cm x 10 cm) of dry soil were selected at several spots alongside roadways and the top 1 - 2 cm of soil from this area were obtained for analysis as free from pebbles and larger pieces of plant material as possible. The soil (about 20 gm) was placed into polyethylene bottles, taken to the laboratory and stirred well before being placed into small individual aluminum dishes. These samples were allowed to dry a minimum of one week at 25°C and then randomly selected for analysis. Soil samples from all the bridge areas contained very fine silt, fine sand and a few small pebbles (< 3 mm diameter). Soil samples from the 98 Avenue, 85 Street traffic circle were composed of black topsoil with decayed and partially decayed vegetable matter.

Without further preparation, triplicates of about 2 gm of each sample were taken from the tops of the samples in the aluminum dishes and accurately weighed to 0.1 mg into polypropylene beakers. Twenty milliliters of one molar nitric acid were pipetted into each beaker and the mixtures were stirred for 0.5 hour with teflon covered magnetic stir bars. The samples were then filtered through

glass-fiber filter mats, quantitatively transferred to 50 ml volumetric flasks and diluted to volume with one molar nitric acid.

The samples were analyzed for lead and cadmium by atomic absorption spectroscopy. Calibration curves were run on each instrument before each sample and concentrations were read off a calibration curve. Standard addition techniques were employed to determine and eliminate matrix effects.

Snow Dump Analysis

During the spring of 1973 grab samples were taken from the two snow dumps located on the river at Whitemud Creek and at Groat Road. The samples consisted of snow (about 250 ml hard packed) from the interior and sand/snow slush (about 250 ml) from the exterior. The samples were processed in the same way as the soil samples, except that five, ten and fifteen gram samples were used and appropriate volumes of concentrated nitric acid were added during the extraction phase to counteract dilution effects.

Water Sample Procedure

During the summers of 1973 and 1974 samples of water were taken from the Edmonton Water Treatment Plant

to determine the amount of lead and cadmium in the raw and finished water. Water samples were taken at the raw water intake, the primary clarifier, the secondary clarifier and the final water flume.

The concentrations were expected to be in the µg/l range which precluded the use of the 290-B spectrometers. Arrangements were made with the Alberta Pollution Control Laboratory to analyze the samples using a flameless atomic absorption spectrometer employing a carbon rod furnace.

Samples were taken in pyrex glass tubes and delivered to the Pollution Control Laboratory. Before analysis each sample was blended ultrasonically to redissolve any metals that may have plated onto the sample container in the interim period.

Air Samples

As Stated in Chapter IV the lack of availability of a portable high volume air sample necessitated using results obtained from the Alberta Department of the Environment samplers.

Large known volumes of air are passed through a filter for twenty-four hours. The filters are collected and sent to the Pollution Control Laboratory for analysis of lead. Samples are taken for five days each month.

Vegetation Analysis Procedures

Vegetation samples were collected on the day they were to be analyzed. Approximately two grams (wet weight) of unwashed plant material were accurately weighed and placed in 250 ml round-bottom flasks. To each flask were added 10 ml concentrated $HClO_4$, 10 ml concentrated HNO_3 and 10 ml demineralized water. The flasks were fitted with a reflux condenser and Bethge apparatus and refluxed at 220°C for four hours [1,2]. The mixture was cooled to room temperature, transferred to a 50 ml volumetric flask and brought up to volume with one molar nitric acid. Samples were then analyzed for lead and cadmium by atomic absorption spectroscopy as previously described.

Difficulties were encountered in dissolving the samples. A white, crystalline precipitate formed which was difficult to filter from the solution. Problems were also encountered with clogging of the asperator and burner slot, necessitating frequent cleaning.

Equipment and Reagent Preparation

All glassware was obtained new and then aged in a concentrated nitric acid bath for 48 hours. It was then rinsed in distilled and demineralized water. Used glassware was washed in distilled water, then concentrated nitric acid, followed by rinses in distilled and demineralized water.

The aluminum soil sample containers were analyzed for lead and cadmium. Samples of dishes (about 4 gm) were weighed to 0.1 mg and dissolved in 50 mls 37% HCl and 30 mls deionized water in a teflon beaker. Sample volume was reduced to 50 mls by slow heating and the cooled solutions were transferred to a 100 ml volumetric flask, diluted to volume with 1 M HNO_3 and analyzed.

The acid extractable lead and cadmium in the glass-fiber filter mats was assessed by passing fifty milliliter aliquots of 1 M HNO_3 through several of the mats and analyzing the filtrate for lead and cadmium.

Samples of deionized water, HNO_3 and HCl were analyzed for lead and cadmium. One liter samples of demineralized water were reduced to about 10 mls by slow heating in a Teflon beaker, diluted to 50 ml with 1 M HNO_3 and analyzed. Five-hundred milliliter samples of concentrated HNO_3 and 37% HCl were reduced to 50 ml., made up to 100 ml with 1 M HNO_3 and analyzed.

All solutions used were prepared using demineralized water.

Discussion of Accuracy

The accuracy of the analytical procedure used for the determination of lead and cadmium in the air and water samples is not known.

The spectrometers used for the soil analysis were reproducable to ±0.5 ppm for lead and ±0.01 ppm for cadmium. For the 50 ml solution and 2 gm of extracted soil, these values correspond to ±12 mg/Kg lead and ±0.25 mg/Kg cadmium in the soil. The extraction procedure utilized has been shown to extract 99.1 ±7.3% of the non-natural lead [1]. The extraction efficiency is higher for cadmium due to the higher solubility of cadmium nitrate. Thus soil data is ±(12 mg/Kg + 7.3%) for lead and ±0.25 mg/Kg for cadmium (see Tables 6-10).

Chapter V

Footnotes

1. John, M.K. Lead contamination of some agricultural soils in western Canada. Env. Sci. Tech. 5 : 1199, 1971.
2. Klein, D.H. Mercury and other metals in urban soils. Env. Sci. Tech. 6 : 560, 1972.
3. Lagerwerff, J.V., Specht, A.W. Contamination of roadside soil and vegetation with Cd, Ni, Pb, Zn. Env. Sci. Tech. 4 : 583, 1970.
4. Motto, H.L., Daines, R.H., Childo, D.M., Motto, C.K. Lead in soils and plants: Its relationship to traffic volume and proximity to highways. Env. Sci. Tech. 4 : 231, 1970.

CHAPTER VI

Test Results and Discussion

Standard Addition Results

Initially it was decided to utilize standard addition techniques for all samples. Subsequent investigations showed that for all cadmium samples and for the less concentrated lead samples the sample signal and large reading errors resulted. The standard addition method was continued for the concentrated lead samples to determine whether matrix effects were present and if so, to what extent. The results for nine samples are shown in Table 5. The mean deviation between samples analyzed with and without standard addition was zero, indicating that there is probably no matrix effect. On this basis the method of standard addition was discontinued for the rest of the samples.

Lead and Cadmium as a Function of Distance

The Data in Table 6 and Figures 10 and 11 show that the soil concentration of lead and cadmium is a function of distance from the emission sit. This is in line with the findings of Lagerwerff and Specht (1970), Goodman and Roberts (1971) and Klein (1972). Indications are that, depending upon prevailing winds and screening objects, the soil lead and cadmium content will probably decrease to

Table 5 . Comparison of Sample and Standard Addition Results for Lead.

Standard Addition [Pb] (mg/Kg)	Sample [Pb] (mg/Kg)	Deviation [Pb] (mg/Kg)
350	350	0
190	210	+20
220	230	+10
230	180	-50
260	260	0
200	210	+10
150	130	-20
130	160	+30
150	150	0

mean deviation $(\bar{d}) = 0$

background levels within about one hundred yards of the emission site.

Examination of Table 11 reveals that for the transect made from the north curb of the circle towards the center, the lead levels tend to be higher than for samples taken from the transect from the south curb towards the center. There are possibly two reasons for this, prevailing winds or heavier traffic flow along one side of the circle. From the traffic flow patterns given in Chapter IV, it would seem that such a traffic distribution is unlikely. A light wind blowing from north to south along 85th Avenue would prevent the light particles from settling on the south end of the circle and the concentration in the south transect should be approximately a constant amount less than for the north transect. For the lead distribution, the mean difference is about 100 mg/Kg; however, for cadmium distribution a similar pattern is not evident.

Anomalies in the distribution (Figures 10,11) are likely due to artifacts, most notably plant material, in the samples.

Lead and Cadmium for the Bridge Sites

In Tables 7 - 10 the data shows that with the exception of the James MacDonald Bridge all soil samples displayed high concentrations of lead. The James MacDonald Bridge values are much lower due to the much shorter

Table 6. Lead and Cadmium Concentration as a Function of Distance from Emission Site - 98 Avenue 85 Street Traffic Circle

*Distance (ft) from curb	[Cd] (mg/Kg)	[Pb] (mg/Kg)
N-3	1.2	350
N-6	.74	260
N-9	.75	220
N-12	.80	220
N-15	.76	230
N-25	.87	210
N-50	.75	210
N-75	.76	160
N-100	.75	91
S-0	1.0	160
S-3	1.0	210
S-6	.77	180
S-9	1.1	150
S-12	.74	89
S-15	.81	160
S-25	.62	130
S-50	.62	64
S-75	.50	63
S-100	.50	27

(Table continued)

Table 6 continued

* a transect was made across the traffic circle co-axial with 85th Street and samples were taken from the north and south curbs towards the center and numbered N-15, S-15, respectively.

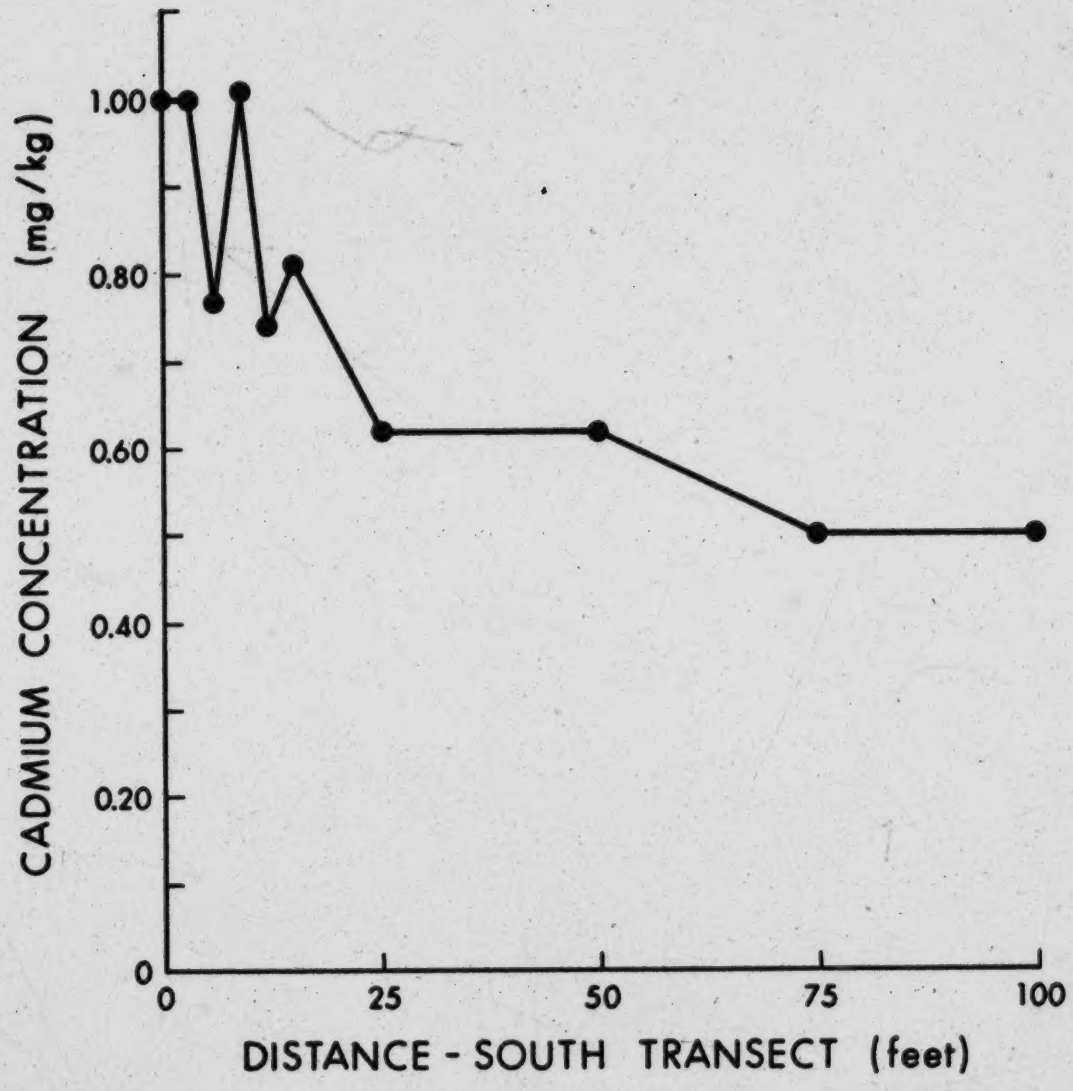


FIGURE 10 - CADMIUM DISTRIBUTION FOR 98 AVENUE 85 STREET TRAFFIC CIRCLE

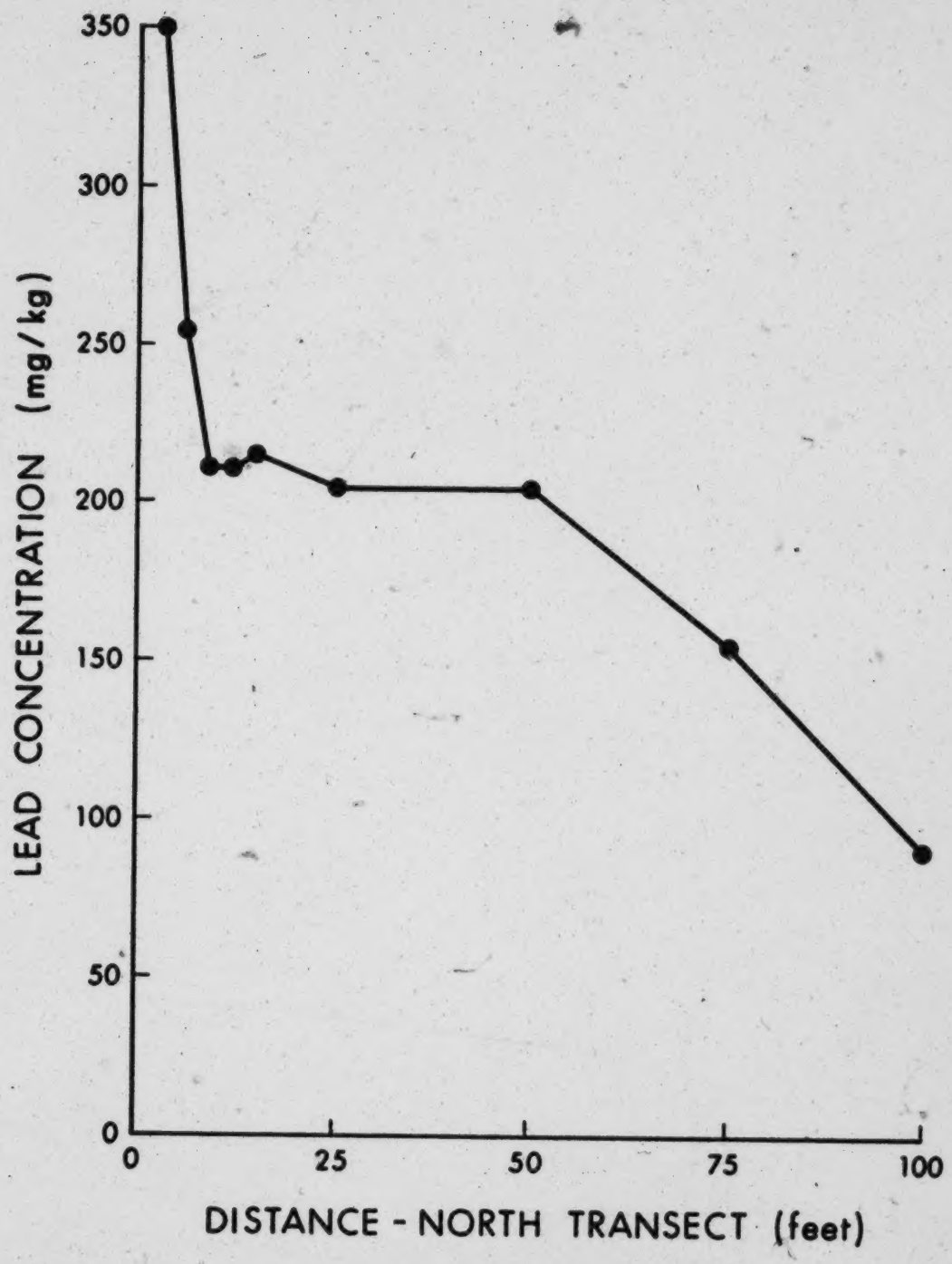


FIGURE II - Lead Distribution For 98 Avenue 85 Street Traffic Circle

Table 7. Lead and Cadmium Concentrations for the vicinity of the 105th Street Bridge.

Site *	[Cd] (mg/Kg)	[Pb] (mg/Kg)
N-W	.75	650
N-E	.99	580
N-C	.75	620
S-E	.75	380
S-W	1.0	490
TC-O	.75	570
TC-100	.75	320
S-100W	.50	59
	mean ($\bar{x}$) = 0.85 (1-5)	mean ($\bar{x}$) = 540 (1-5)

*N-W - north end of bridge, south bound lane, right curb, about 10 ft. from entrance.

N-E - right curb, north bound lane, north end of bridge

N-C - median, south tip, north end of bridge

S-E - south end of bridge, right side of north bound lane

S-W - south end of bridge, right side of south bound lane

S-100W - 100 ft. west into park, south end of bridge

Tc-O - edge of traffic circle closest to bridge, north end of bridge

Tc-100 - 100 ft. into traffic circle, co-axial with 105 Street, north end of bridge

Table 8. Lead and Cadmium Concentrations for the Vicinity of the James MacDonald Bridge

Site *	[Cd] (mg/Kg)	[Pb] (mg/Kg)
SS	.50	25
SNN	.50	84
SSC	.75	79
NN	.75	87
NS	.75	190
NC	1.2	37
	mean ($\bar{x}$) = 0.74	mean ($\bar{x}$) = 84

*SS - south side exit, right curb of south bound lane

SNN - south side exit, right curb of north bound lane

SSC - south side exit, center of dividing median

NN - north side exit, right curb of north bound lane

NS - north exit, right curb of south bound lane

NC - north exit, median

Table 9. Lead Concentrations for the Vicinity of the Low Level Bridge

Site*	[Pb] (mg/Kg)
NW	720
NE	420
NC	190
SW	110
SE	600
	mean ($\bar{x}$) = 410

*NW - north side entrance, 1 ft from curb, 50 ft from entrance

NE - north side exit, 1 ft from curb, 50 ft from exit

NC - median, 50 ft from entrance

SW - south side exit, 6 ft from curb, 100 ft from exit

SE - south side entrance, 6 ft from curb, 75 ft from entrance

Table 10. Lead Concentrations for the Vicinity of the High Level Bridge

Site *	[Pb] (mg/Kg)
S-W	530
S-E	700
N-E	430
N-W	100
N-EC	94
N-WC	36
	mean ($\bar{x}$) = 310

*S-W - south exit, right side south bound lane, 6 ft from curb, ~ 50 ft from exit.

S-E - right side of north bound lane, 5 ft from curb ~ 50 ft from entrance

N-E - north exit, exit lane, 6 ft from curb, ~ 50 ft from entrance

N-W - north entrance, entrance lane, 6 ft from curb, ~ 50 ft from exit.

N-EC - median, 1 ft from curb, 50 ft from exit

N-WC - median, 1 ft from curb, 50 ft from entrance

time it has been in service (about three years). For all four bridges however, concentrations are similar to those found in locations investigated by other researchers.

For three of the bridge sites, the High Level, the Low Level and the James MacDonald, there are anomalies in the results. As soil lead concentrations are expected to accumulation with time, any activity which removes, covers up or adds to former depositions will result in concentrations for that area being lower or higher than for the surrounding area. It therefore appears necessary to take several samples at widely separated points when determining lead concentrations for that area.

At the 105th Street Bridge, in addition to the bridge samples at the entrance and exit, two samples were taken in the traffic circle at the north end of the bridge and one sample was taken in Kinsmen Park about 100 feet west of the south end of the bridge. The two circle samples display high lead levels but the park sample was low.

Cadmium levels for all locations sampled displayed large deviations in concentration. For all cadmium samples processed (including the 98th Avenue, 85th Street, traffic circle) the mean was 0.78 mg/Kg with a range 0.50 - 1.2 mg/Kg. This can be compared to the results of Klein (1972) who gave means of 0.41 mg/Kg and 0.57 mg/Kg for residential and agricultural areas respectively and John (1972) who gives a mean of 0.88 mg/Kg for agricultural areas.

As the results showed that the total cadmium concentrations were low, analyses for this element were not made at the High Level Bridge and Low Level Bridge locations.

Lead and Cadmium in Snow and Water

The maximum concentrations of lead (0.014 mg/l) and cadmium (0.004 mg/l) from the water analyses in the summers of 1973 and 1974 are much less than the limits of 0.05 mg/l for lead and 0.01 mg/l for cadmium as given in the Canadian Drinking Water Standards (1968) (Tables 11,12). As there is little inflow of storm sewage during fall and winter it is probable that similar conditions prevail during these seasons.

Examination of Tables 11 and 12 shows that for some occasions the final water contained higher concentrations of lead and cadmium than the raw water. It is possible that this can be attributed to trace: contaminants in the chemicals added during the water treatment processes, adsorption phenomena on the sample container walls or instrumentation errors (the concentrations being determined are very close to instrument detection limits).

Data are not available for the WTP for the spring runoff period, when it is expected that lead and cadmium levels will be the highest. The Pollution Control Laboratory was reluctant to analyze the samples provided

because of a large sample backlog at this time due to Provincial Department of the Environment spring sampling programs.

No data are available from the Department of the Environment concerning lead and cadmium levels in the river at this time.

Data from the 1973 snow dump samples analyzed showed that any lead present was in a concentration below 2 mg/Kg. No cadmium tests were performed.

Table 11. Lead and Cadmium in Raw and Municipal Water of the City of Edmonton in Summer 1973.

Location		Date				
		4/6/73	11/6/73	18/6/73	25/6/73	9/7/73
final water (mg/l)	Cd	.001	.001	.001	.001	.001
	Pb	.002	.001	.001	.002	.008
raw water (mg/l)	Cd	<.001	<.001	<.001	<.001	<.001
	Pb	.002	.005	<.001	.010	.003
#1 primary clarifier (mg/l)	Cd	.001	.001	.001	.004	.001
	Pb	.002	.001	.001	.006	.001
#1 secondary clarifier (mg/l)	Cd	.001	.001	.001	.001	.001
	Pb	.002	.002	.014	.002	.002

Table 12. Lead and Cadmium in Raw and Municipal Water in the City of Edmonton in Summer 1974.

Date	Raw (mg/l)		Treated (mg/l)	
	Cd	Pb	Cd	Pb
14/5/74	<.001	<.001	<.001	<.001
23/5/74	<.001	.005	<.001	<.001
14/6/74	<.001	<.001	<.001	<.001
24/6/74	<.001	<.001	<.001	<.001
2/7/74	<.001	<.001	<.001	<.001
5/7/74	<.001	<.001	<.001	<.001
9/7/74	<.001	<.001	<.001	<.001
12/7/74	<.001	<.001	.002	<.001
16/7/74	<.001	<.001	<.001	<.001
19/7/74	<.001	<.001	<.001	<.001
23/7/74			<.001	<.001
26/7/74	<.001	<.001		
30/7/74	.001	<.001	<.001	.005

Vegetation Data

The vegetation samples proved difficult to analyze. The digestion method used failed to completely dissolve the plant material and the solutions tended to clog the burner aspirator. Results obtained for three sets of samples indicated less than 12 mg/Kg of lead and less than 0.25 mg/Kg of cadmium.

Air Sample Data

Analyses for cadmium were not performed on air samples by the Alberta Department of the Environment.

Tables 13 and 14 give the provincial government data for atmospheric lead in Edmonton for 1973 and 1974. Data for the residential (92 Avenue, 146 Street), industrial (17 Street, 106 Avenue) and downtown (102 Avenue, 100 Street) sites can be compared to the Russian and California standards of 0.01 mg/m^3 and 0.20 mg/m^3 respectively. Downtown means (0.3 $\mu g/m^3$, 0.5 $\mu g/m^3$) are usually higher than residential or industrial means (0.2 $\mu g/m^3$, 0.3 $\mu g/m^3$ and 0.1 $\mu g/m^3$, respectively).

Statistical Treatment of Data

Samples for soil and water analysis were analyzed in triplicate so that a statistical analysis could be performed on the raw data. Air pollution data was supplied

Table 13. Atmospheric Lead Concentrations in Edmonton - 1973

Source - Alberta Environment (1974)

	Mean concentration ($\mu g/m^3$)		
Month	Residential	Industrial	Downtown
Jan	0.4	0.2	0.6
Feb	0.1	0.1	0.2
Mar	0.3	0.2	0.4
Apr	0.1	0.04	0.1
May	0.1	0.1	0.1
June	0.1	0.2	0.1
July	0.06	0.1	0.2
Aug			
Sept	0.1	0.1	0.2
Oct	0.2	0.1	0.4
Nov	0.3	0.3	0.4
Dec	0.4	0.2	0.4
Mean and mean deviation	0.2±0.1	0.1±0.06	0.3±0.2

Table 14. Atmospheric Lead Concentrations in Edmonton - 1974

Source - Alberta Environment (1974)

Month	Mean concentration ($\mu g/m^3$) Residential	Industrial	Downtown
Jan	0.1	0.1	0.3
Feb	0.4	0.3	0.3
Mar	0.3	0.2	0.4
Apr	0.3	0.3	0.7
May	0.3	0.3	0.7
June	0.3	0.2	0.6
Mean and mean deviation	0.3±0.05	0.2±0.07	0.5±0.2

by the Alberta Department of the Environment in a finished form and all samples were run singly so that no analysis could be performed on raw data.

The statistical test used was the critical value test for the rejection of extreme values [2]. The test is based on the ratio of the difference between the highest and lowest values of all values (R_1) and the difference between the highest and lowest values excluding the value which is suspect (R_2). If the ratio exceeded the particular critical value for that number of samples then the suspected value was excluded. The 95% probability level was used and the critical value at this level for three samples was $R_1/R_2 = 16.9$

Analysis of Reagents

It was necessary to know if significant amounts of lead or cadmium were present in the chemicals used in the analyses. The analysis of the aluminum dishes, glass-fiber filter mat extracts, HNO_3, HCl and demineralized water showed the following:

1) <5 mg/Kg Pb and <0.1 mg/Kg Cd in the aluminum dishes
2) <0.5 mg/l Pb and <0.01 mg/l Cd in the mat extracts
3) <0.2 mg/l Pb and <0.001 mg/l Cd in the demineralized water
4) <0.05 mg/l Pb and <0.001 mg/l Cd in the concentrated HCl and HNO_3

It was concluded that the aforementioned were not a likely source of lead and cadmium contamination in the soil analyses.

Chapter VI

Footnotes

1. Canadian Drinking Water Standards and Objectives - 1968, Department of National Health and Welfare, Canada (1974).

2. Fischer, R.B., Peters, D.G. Quantitative Chemical Analysis 3rd edition, W.B. Saunders Co., Toronto, 1968.

3. Goodman, G.T., Roberts, T.M. Plants and soils as indicators of metals in the air. Nature 231 : 287, 1971.

4. John, M.K. Cadmium contamination of soils and its uptake by oats. Env. Sci. Tech. 6 : 555, 1972.

5. Klein, D.H. Mercury and other metals in urban soils. Env. Sci. Tech. 6 : 560, 1972.

6. Lagerwerff, J.V., Specht, A.W. Contamination of roadside soil and vegetation with Cd, Ni, Pb, Zn. Env. Sci. Tech. 4 : 583, 1970.

CHAPTER VII

Summary and Recommendations

Lead and Cadmium in Edmonton Soils

Definite soil lead pollution from automobile exhausts exists in the areas around four of Edmonton's bridges, indicating that a similar situation is likely to exist along all major traffic routes. Soil lead concentrations appear to be a function of traffic volume, the time an area has been subjected to traffic flow and distance from the emission zone. The amount of lead pollution is comparable with levels found in similar situations by other researchers [5,7,9].

The mean level of soil cadmium (0.8 mg/Kg) was found to be almost twice the concentration accepted as the usual urban value (0.41 mg/Kg). Cadmium concentrations were shown to decrease with distance from the emission site as has been observed in other studies, but little variation with traffic volume or the time the area was subjected to cadmium pollution was observed. The variation in cadmium concentration with distance indicates that automobiles are a source of the metal.

Dilute nitric acid extraction of soil samples followed by atomic absorption spectroscopy was found to be a fairly fast, accurate method of lead and cadmium with no matrix effects being observed.

Lead and Cadmium in Edmonton Municipal Water

Analyses of 1973 and 1974 showed that summer levels of the metals were minimal (Pb - 0.014 mg/l, Cd - 0.004 mg/l), certainly well within accepted standards (Pb - 0.05 mg/l, Cd - 0.01 mg/l). It can be estimated that fall and winter concentrations should be of the same order of magnitude as there is minimal influx of local runoff water to the river at this time.

Spring runoff imposes a different situation and no interpolation from summer results should be made. Estimates of the total urban lead and cadmium loadings for a six month period indicate that levels at this time can be substantial. Pitt and Field (1974) give an urban street loading of 103 Kg/day for lead and 0.19 Kg/day for cadmium for a city of 100,000 people, based on results of a U.S. Environmental Protection Association study. On a similar basis, assuming no removal for six thirty-day months and a 500,000 person population, the Edmonton loading should be 92,700 Kg for lead and 171 Kg for cadmium. Data from Automobile Emission Trends in Canada 1960 - 1985 (1973), the Alberta Department of Highways [2] and the Alberta Department of the Environment [1] also allows calculation of total lead loadings. For 200,000 automobiles 1.75 g/gal of lead, 8,000 miles/year (city driving) and 15 mpg average the thirty day, six month lead loading can be calculated as 92,800 Kg.

The results of grab samples from two snow dumps seem to indicate that contamination from this source may be low, but it should be considered that the samples may not have been representative.

Lead and Cadmium in Edmonton Air

Permissible limits for lead and its organic compounds in particulate form in air range from 0.7 $\mu g/m^3$ (Russia) to 1.5 $\mu g/m^3$ (California) [4] and the lead content of urban air in the U.S. has been given as 0.05 $\mu g/m^3$ [10]. Edmonton means vary from 0.06 - 0.7 $\mu g/m^3$, indicating that atmospheric contamination be lead aerosols exists.

Mean daytime and mean rush hour traffic air lead concentrations can be expected to substantially higher than monthly means. Results from other researchers indicate that mean air lead concentrations in heavy traffic are about ten times the mean daily concentrations. This would give a value of about 3 $\mu g/m^3$ of lead for Edmonton.

A nation-wide air sampling program in the United States [3] showed that communities with populations of less than 100,000 people experienced ambient air concentrations of 1.7 $\mu g/m^3$. In all air pollution studies it has been found that the lead concentrations in a city center are substantially higher (by a factor of 3-5) [8] than in the suburbs. In view of this the data indicating that the lead levels in the city center are about 0.3 $\mu g/m^3$ are anomalous.

The downtown sampler is located on the roof of the Edmonton Public Library and is about forty feet above the street while the industrial and residential samplers are located at ground level. The work of Kobayashi, et al., (1970) shows that the location of the sampler affects the results and it is likely that the low results reflect the sampler location.

No data is available for atmospheric cadmium levels, but indications are that they tend to be about one per cent of the lead levels [6].

Effects of Future Gasoline Lead Regulations

The United States Environmental Protection Agency has established a schedule (Table 15) for the reduction of gasoline lead content. Indications are that Environment Canada intends to follow these regulations for Canada [13]. These regulations would result in a substantial decrease in lead contamination of the environment.

While air and water lead levels respond immediately to decreased lead levels, no data is available on the half-life of lead in various soils. On the basis of present data, indications are that soil lead would be likely to remain for several years.

A reduction of gasoline lead would have no effect upon cadmium levels, and they can be expected to increase if the metal remains as a trace contaminent in tires and motor oils.

Table 15. Environmental Protection Association (U.S.) Schedule for Gasoline Lead Reductions

Source - Environment Canada, 1974

Date	[Pb] (gm/Imp. gal.)
Jan 1, 1974	<0.07 (non-leaded)
	<3.1 (other grades)
Jan 1, 1975	<2.1
Jan 1, 1976	<1.75
Jan 1, 1977	<1.25
Jan 1, 1978	<1.0
Jan 1, 1979	<0.6

Recommendations

It has been shown that Edmonton suffers from lead pollution and, to a much lesser degree, cadmium pollution. The research served as a preliminary investigation and should be followed up by additional studies. It is recommended that the studies include the following:

1) A check to see whether the present air quality monitoring gives representative values of actual lead and cadmium levels in the atmosphere at street levels.
2) An assessment of drinking water lead and cadmium levels during spring runoff.
3) An evaluation of blood lead levels in the general populace if the results of 1) and 2) indicate substantial pollution.
4) Determination of lead and cadmium levels in grass and other crops grown in soils that are contaminated, specifically hay harvested from road ditches and medians.
5) Evaluation of air lead and cadmium levels in dwellings along major roadways, specifically hi-rise apartments.

Chapter VII

Footnotes

1. Private communication, July, 1974.
2. Private communication, July, 1974
3. Hall, S.K. Pollution and poisoning. Env. Sci. Tech. 6 : 31, 1972.
4. Craig, P.P., Berlin, E. The air of poverty Environment 13 : 2, 1971.
5. Klein, D.H. Mercury and other metals in urban soils. Env. Sci. Tech. 6 : 560, 1972.
6. Kobayashi, Y., Hori, M., Tsuchiya, K. Keio Journal of Medicine 19 : 183, 1970.
7. Lagerwerff, J.V., Specht, A.W. Contamination of roadside soil and vegetation with Cd, Ni, Pb, Zn. Env. Sci. Tech. 4 : 583, 1970.
8. Lee, Jr., R.E., Patterson, R.K., Wagman, J. Particle-size distribution of metal components in urban air. Env. Sci. Tech. 2 : 288, 1968.
9. Motto, H.L., Daines, R.H., Chilko, D.M., Motlo, C.K. Lead in soils and plants: Its relationship to traffic volume and proximity to highways. Env. Sci. Tech. 4 : 231, 1970.
10. Patterson, C.C. Contaminated and natural lead environments of man. Arch. Env. Health 11 : 344, 1965.

11. Pitt, R.E., Field, R. Water quality effects from urban runoff. AWWA Conferences, Boston, 1974.

12. Taylor, G.W. Automobile Emission Trends in Canada, 1960-1985. Environmental Impact and Assessment Report EPS 8-AP-73-1 Environment Canada, 1973.

13. Private communication, Environment Canada, July, 1974.

Bibliography

1. Atkins, P.R. Lead in a suburban environment. JAPCA 19 : 591, 1969.
2. Bazell, R.J. Lead poisoning: Zoo animals may be first victims. Science 173 : 130, 1970.
3. Blanc, B., Hofmann, W., Basset, J., Graber, H., Liechti, D., Bovay, E. Schweizeriche Landwirt Schaftliche Forchung 9 : 159, 1970.
4. Bovay, E. Schwezeriche Gesellschaft fuer Analytiche und Angewandte Chemie 61 : 303, 1970.
5. Bovay, E., Hofmann, W., Zuber, R., Kuepfer, U., Gisiger, L., Blanc, B. ibid 9 : 159, 1970.
6. Brief, R.S. Air lead concentrations from automobile engines AEH 5 : 527, 1962.
7. Brief, R.S., Jones, A.R., Yoder, J.D. Lead, carbon monoxide and traffic: A correlation study. JAPCA 10 : 384, 1960.
8. Campbell, I.M., Mergand, E.G. Biological Aspects of Lead: An Annotated Bibliography. U.S. Environmental Protection Agency (1972).
9. Canadian Drinking Water Standards and Objectives - 1968 Department of National Health and Welfare, Canada (1974).
10. Cannon, H.L., Bowles, J.M. Contamination of vegetation by tetraethyl lead. Science 137 : 765, 1962.

11. Charlson, R.J., Pierroid, J.M. Visibility and lead Atm. Env. 3 : 479, 1969.

12. Chisolm, Jr., J.J. Lead poisoning. Scientific Am. 224 : 15, 1971.

13. Chow, T.J., Earl, J.L. Lead aerosols in the atmosphere: Increasing concentrations. Science 169 : 577, 1970.

14. Chow, T.J., Earl, J.L., Bennett, C.F. Lead aerosols in marine atmospheres. EST 3 : 737, 1969.

15. Chow, T.J., Johnstone, M.S. Lead aerosols in gasoline and aerosols of Los Angeles basin, California. Science 147 : 502, 1965.

16. Colucci, J.M., Begeman, C.R., Kumler, K. Lead contamination in Detroit, New York and Los Angeles air. JAPCA 19 : 255, 1969.

17. Craig, P.P., Berlin, E. The air of poverty. Environment 13 : 2, 1971.

18. deBruin, A. Certain biological effects of lead upon the animal organism. AEH 23 : 249, 1971.

19. Fischer, R.B., Peters, D.G. Quantitative Chemical Analysis 3rd edition, W.B. Saunders Co., Toronto, 1968.

20. Georgii, H.W., Jost, D. Short communication: On the lead concentration in an urban aerosol. Atm. Env. 5 : 725, 1971.

21. Gillette, D.A. A study of aging of lead aerosols - II. Atm. Env. 6 : 451, 1972.

22. Gillette, D.A., Winchester, J.W. A study of aging of lead aerosols - I. Atm. Env. 6 : 433, 1972.

23. Goldsmith, J.R. Epidimiological bases for possible air quality criteria for lead. JAPCA 19 : 714, 1969.

24. Goldwater, L.J., Hoover, A.W. An international study of normal levels of lead in blood and urine. AEH 15 : 60, 1967.

25. Goodman, G.T., Roberts, T.M. Plants and soils as indicators of metals in the air. Nature 231 : 287, 1972.

26. Goyer, R.A., Leonard, D.L., Moore, J.F., Rhyne, B., Kregman, M.R. Lead dosage and the role of the intranuclear inclusion body. AEH 20 : 705, 1970.

27. Grundy, R.D. Summary: Toxicological and epidemiological bases for air quality criteria. JAPCA 19 : 730, 1969.

28. Hall, S.K. Pollution and poisoning. EST 6 : 31, 1972.

29. Hardy, H.H. Discussion of article by Kehoe. JAPCA 19 : 701, 1969.

30. Hardy, H.L. Lead and health. Environment 10 : 80, 1968.

31. Hernberg, S., Nikkanen, J. Enzyme inhibition by lead under normal urban conditions. Lancet 1 : 63, 1970.

32. Hickey, R.J., Schoff, E.P., Clelland, R.C. Relationship between air pollution and certain chronic disease death rates. AEH 15 : 278, 1967.

33. Jeffries, D.J., French, M.C. Lead concentrations in small mammals trapped on roadside verges and field sites. Evn. Polln. 3 : 147, 1972.

34. John, M.K. Lead contamination of some agricultural soils in Western Canada. EST 5 : 1199, 1972.

35. John, M.K. Cadmium contamination of soils and its uptake by oats. EST 6 : 555, 1972.

36. John, M.K. Cadmium uptake by eight different food crops as influenced by various soil levels of cadmium. Env. Polln. 4 : 7, 1973.

37. Junge, C.E. Air Chemistry and Radioactivity. Academic Press, New York, 1963.

38. Kehoe, R.A. Toxicological appraisal of lead in relation to the tolerable concentration in the ambient air. JAPCA 19 : 690, 1969.

39. Klein, D.H. Mercury and other metals in urban soils. EST 6 : 560, 1972.

40. Kobayashi, Y., Hori, M., Tsuchiya, K. Kleo Journal of Medicine 19 : 183, 1970.

41. Lagerwerff, J.V., Specht, A.W. Contamination of roadside soil and vegetation with Cd, Ni, Zn, Pb. EST 4 : 583, 1970.

42. Landau, E., Smith, R., Lynn, D.A. Carbon monoxide and lead: An environmental appraisal. JAPCA 19 : 684, 1969.

43. Lazarus, A.L., Lorenge, E., Lodge Jr., J.P. Lead and other metal ions in U.S. precipitation. EST 4 : 55, 1970.

44. Lee Jr., R.E., Patterson, R.K., Wageman, J. Particle-size distribution of metal components in urban air. EST 2 : 289, 1968.

45. Ludwig, J.H., Diggs, D.R., Hesselburg, H.E., Maya, J.A. Survey of lead in the atmosphere of three urban communities: A summary. J. Amer. Ind. Hyz. Ass. 26 : 270, 1965.

46. McMullen, T.B., Faaro, R.B., Morgan, G.B. Profile of pollutant fractions in nonurban suspended particulate matter. JAPCA 20 : 369, 1970.

47. Miller, J.A., Battistini, V., Cumming, R.L.C., Carswell, F., Goldberg, A. Lead and δ-aminolevulinic acid dehydratase levels in mentally retarded children and in lead-poisoned suckling rats. Lancet 1 : 695, 1970.

48. Morgan, M.J. Normal lead and cadmium content of the human heart. AEH 24 : 364, 1972.

49. Motto, H.L., Daines, R.H., Chilko, D.M., Motto, C.K. Lead in soils and plants: Its relationship to traffic volume and proximity to highways. EST 4 : 231, 1970.

50. Oliver, B.C. Heavy metal levels of Ottawa and Rideau River sediments. EST 7 : 135, 1973.

51. Patterson, C.C. Contaminated and natural lead environments of man AEH 11 : 344, 1965.

52. Pitt, R.E., Field, R. Water quality effects from urban runoff. AWWA Conference, Boston, U.S.A., 1974.

53. Schroeder, H.A. Cadmium as a factor in hypertension. J. Chron. Dis. 18 : 647, 1965.

54. Schroeder, H.A. A sensible look at air pollution by metals. AEN 21 : 798, 1970.

55. Schroeder, H.A., Babassa, J.J. Abnormal trace metals in man: Cadmium. J. Chron. Dis. 14 : 236, 1961.

56. Schroeder, H.A., Tipton, I.H. The human body burden of lead. AEH 17 : 965, 1968.

57. Smith, W.H. Lead and mercury burden of urban woody plants. Science 176: 1237, 1972.

58. Stanhovic, M.K. Biochemical tests for the appraisal of exposure to lead. AEH 23 : 265, 1971.

59. Tatsimoto, M., Patterson, C.C. Concentrations of common lead in some Atlantic and Mediterranean waters and in snow. Nature 199 : 350, 1963.

60. Taylor, G.W. Automobile Emission Trends in Canada 1960-1985. Environmental Impact and Assessment Report EPS 8-AP-73-1 Environment Canada, 1973.

61. Thomas, H.V., Milmore, B.K., Neidbreder, G.A., Kogan, B.A. Blood lead levels in persons living near freeways. AEH 15 : 695, 1967.

62. Weber, C.W., Reid, B.L. Effect of dietary cadmium on mice. Tox. Appl. Pharm. 14 : 420, 1967.

63. Wilson Jr., E.B. An Introduction to Scientific Research, McGraw-Hill, New York, 1952.

64. Winchester, J.W., Zoller, W.H., Duce, R.A., Benson, C.S. Lead and halogens in pollution aerosols and snow from Fairbanks, Alaska. Atm. Env. 1 : 105, 1967.

APPENDIX

Table A - Raw Soil Data For 98 Avenue, 85 Street Traffic Circle

Sample	Spectrometer reading		Sample wt.	[ ] mg/Kg		mean	
	Pb	Cd		[Pb]	[Cd]	Pb	Cd
S-0	.13	.03	1.9889	160	.70	160	1.0
	.13	.06	2.0309	160	1.5		
	.12	.03	1.9809	150	.90		
S-3	.18	.04	2.0150	230	1.1	210	1.0
	.16	.04	2.0737	220	1.1		
	.14	.04	1.9339	180	.90		
S-6	.18	.03	2.0280	230	.74	180	.77
	.16	.03	1.9953	180	.75		
	.14	.03	1.9626	180	.83		
S-9	.12	.04	1.9878	150	1.0	150	1.1
	.11	.04	2.0239	140	1.1		
	.12	.14	1.9688	150	3.6		
S-12	.06	.03	2.0167	68	.75	89	.74
	.07	.07	1.9914	88	1.4		
	.09	.03	2.0696	110	.72		
S-15	.14	.04	2.0020	170	.87	160	.81
	.13	.02	1.9959	160	.63		
	.13	.04	2.0010	150	.94		
S-25	.12	.02	2.0394	150	.61	130	.62
	.10	.02	1.9498	130	.51		
	.08	.03	2.0116	110	.75		
S-50	.05	.02	1.9677	64	.64	64	.62
	.06	.02	2.1428	76	.58		
	.05	.02	1.9125	65	.65		
S-75	.05	.02	1.9826	63	.50	63	.50
	.05	.02	1.9906	63	.50		
	.04	.02	2.0366	27	.54		
S-100	.02	.02	1.9692	25	.51	27	.50
	.02	.02	2.0020	28	.50		
	.02	.02	2.0101	27	.50		

Table A - Continued

	Pb	Cd		[Pb]	[Cd]	Pb	Cd
N-3	.33	.06	2.2353	370	1.1	350	1.2
	.24	.04	1.8750	320	1.3		
	-	-	-	-	-		
N-6	.21	.03	1.9975	260	.75	260	.74
	.15	.03	1.9136	200	1.4		
	.22	.04	2.0701	260	.72		
N-9	.18	.03	1.9975	220	.75	220	.83
	.18	.03	2.0004	230	.78		
	.16	.05	2.0199	200	.97		
N-12	.16	.04	1.9855	210	1.0	220	.80
	.18	.03	2.0107	220	.75		
	.17	.02	1.9729	220	.63		
N-15	.18	.12	2.1175	210	2.7	230	.76
	.19	.03	1.9030	250	.79		
	.19	.03	2.0317	240	.74		
N-25	.17	.04	2.0176	210	.87	210	.87
	.18	.04	2.0194	220	.87		
	.16	.03	1.9648	200	.76		
N-50	.16	.03	2.0101	200	.75	210	.75
	.18	.03	2.0279	220	.80		
	.16	.03	1.9945	210	.75		
N-75	.13	.03	1.9798	160	.76	160	.75
	.14	.03	1.9914	180	.75		
	.12	-	2.0036	150	-		
N-100	.08	.03	1.9998	91	.75	91	.75
	.08	.03	2.0002	91	.75		
	.08	.03	2.0190	90	.74		

$[Pb]_{soil}$ =

(corrected instr. read.) x 5.0 x $\frac{50}{1000}\ell$ x $\frac{1000}{\#gm\ sample}$ Kg^{-1}

corrected instrument reading from calibration curve

$$\frac{50}{1000}\ell \times \frac{1000}{\#gm\ sample}\ Kg^{-1}$$

[Cd] mg/Kg =

(instr. read.) x $\frac{50}{1000}\ell$ x $\frac{1000}{\#gm\ sample}$ Kg^{-1}

Table B - Raw Data For 105 Street Bridge

Sample	Spectrometer reading		Sample Wt.	[ ] mg/Kg		mean	
	Pb	Cd		[Pb]	[Cd]	[Pb]	[Cd]
NW	.47	.03	1.9843	600	.75	640	.75
	.53	.03	2.0124	750	.74		
	.45	.03	2.0120	580	.75		
NW	.46	.02	1.9709	600	.51	640	.67
	.45	.03	2.0174	580	.74		
	.52	.03	1.9934	750	.75		
SE	.22	.03	2.0044	270	.75	380	.75
	.32	.03	2.0026	410	.75		
	.35	.03	2.0150	450	.74		
SE	.32	.03	2.0169	410	.74	400	.66
	.30	.02	1.9871	390	.50		
	.31	.03	2.0072	400	.75		
S-100W	.03	.02	2.0131	37	.50	59	.50
	.05	.02	1.9980	63	.50		
	.06	.02	1.9861	76	.50		
NC	.43	.03	1.9849	560	.76	620	.75
	.43	.03	1.9923	550	.75		
	.58	.03	2.0185	760	.74		
SW	.44	.04	1.9910	560	1.0	490	1.0
	.34	.04	1.9998	440	1.0		
	.37	.04	2.0017	470	1.0		
NE	.50	.04	2.0103	650	.99	580	.99
	.42	.04	2.0113	560	.99		
	.41	.04	2.0369	520	.88		
TC-O	.45	.03	1.9900	590	.75	570	.75
	.41	.03	1.9955	530	.75		
	.47	.03	2.0004	600	.75		
TC-100	.25	.03	1.9823	320	.76	320	.75
	.27	.03	2.0024	340	.75		
	.24	.03	2.0064	300	.75		

Table C - Raw Data For James MacDonald Bridge

Sample	Spectrometer reading		Sample Wt.	[ ] mg/Kg		mean	
	Pb	Cd		Pb	Cd	Pb	Cd
SS	.02	.02	2.0058	25	.50	25	.50
	.02	.02	2.0053	25	.50		
	-	-					
SN	.06	.02	2.0015	75	.50	83	.50
	.07	.02	1.9726	89	.51		
	.07	.02	2.0147	87	.50		
SSC	.07	.03	1.9974	87	.75	79	.75
	.06	.03	2.0078	75	.75		
	.06	.03	1.9840	76	.76		
NN	.07	.03	1.9905	88	.75	87	.75
	.08	.03	2.0015	100	.76		
	.06	.03	2.0170	74	.74		
NS	.15	.03	2.0127	190	.74	190	.75
	.16	.03	2.0020	200	.75		
	.15	.03	1.9773	190	.76		
NSC	.03	.05	2.0073	37	1.2	37	1.2
	.04	.05	1.9775	50	1.3		
	.03	.05	2.0152	37	1.2		

Table D - Raw Data For High Level Bridge

Sample	Spectrometer reading	Sample Wt.	[Pb] mg/Kg	mean [Pb]
NWC	.02	2.0194	25	36
	.04	1.9800	44	
	.03	1.9854	38	
SW	.34	1.9828	440	530
	.39	2.0151	530	
	.48	1.9734	630	
NEC	0.08	2.0118	93	94
	0.08	1.9942	94	
	0.08	1.9922	94	
NE	.37	2.0641	460	430
	.32	1.9562	420	
	.30	1.9428	400	
SE	.56	2.0031	720	700
	.48	1.9604	640	
	.56	1.9794	750	
NW	.08	2.0971	95	100
	.08	2.0971	100	
	.08	1.9493	100	

Table E - Raw Data For Low Level Bridge

Sample	Spectrometer reading	Sample Wt.	[Pb] mg/Kg	mean [Pb]
NW	.52	2.0403	660	720
	.44	2.0150	790	
	-			
SE	.48	1.9230	650	600
	.49	1.9507	670	
	.43	2.1356	520	
NE	.36	2.0639	450	420
	.32	1.9951	410	
	.28	1.9635	390	
NC	.16	1.9984	190	190
	.15	2.0089	190	
	.18	212126	200	
SW	.08	1.8703	110	110
	.09	2.1224	110	
	107	1.9948	88	

Table F - Raw Data For Snow Dumps

Sample	Spectrometer reading	Sample Wt.	[Pb] mg/Kg	mean [Pb]
Groat				
snow-	.00	5.2526	0	0
(interior)	.00	10.1298	0	
	.00	15.2398	0	
sand/slush-	.20	4.9973	100	100
(surface)	.36	10.1156	91	
	.55	15.2860	100	
Whitemud				
snow-	0.00	5.1632	-	0
(interior)	.00	10.7043	-	
	.00	15.1546	-	
sand/slush-	.18	4.7882	94	100
(surface)	.43	10.1073	110	
	>1.00	15.5138		
River				
snow-	.00	5.3423	-	0
(surface)	.00	10.0245	-	